SECTION 6.0

BUTADIENE EMISSIONS FROM MOBILE SOURCES

This section describes estimation methods for butadiene as one component of mobile source hydrocarbon emissions, based on work by EPA's Office of Mobile Sources (OMS). Butadiene emissions are formed in engine exhaust by the incomplete combustion of the fuel. Based on the available data, butadiene emissions appear to increase roughly in proportion to hydrocarbon emissions. Because hydrocarbon emissions are greater from noncatalyst-controlled engines than from catalyst-equipped engines, butadiene emissions are expected to be higher from noncatalyst-controlled engines, such as those in lawnmowers and chainsaws.[17]

Levels of butadiene in gasoline and diesel fuel are expected to be insignificant because butadiene tends to readily form a varnish that can be harmful to engines; therefore, refiners try to minimize the butadiene content. As a result, it was assumed that butadiene is not present in evaporative, refueling, or resting emissions.[17]

6.1 ON-ROAD MOBILE SOURCES

Results of work by the OMS on toxic emissions from on-road motor vehicles are presented in the 1993 report *Motor Vehicle-Related Air Toxics Study* (MVATS).[17] This report was prepared in response to Section 202(l)(1) of the 1990 Clean Air Act Amendments which directs EPA to complete a study of the need for, and feasibility of, controlling emissions of toxic air pollutants that are unregulated under the Act and are associated with motor vehicles and motor vehicle fuels. The report presents composite emission factors for several toxic air pollutants, including butadiene.

The emission factors presented in the MVATS were developed using currently available emissions data in a modified version of the EPA's MOBILE4.1 emission model (designated MOBTOX) to estimate toxic emissions as a fraction of total organic gas (TOG) emissions. All exhaust mass fractions were calculated on a vehicle by vehicle basis for six vehicle types: light-duty gasoline vehicles, light-duty gasoline trucks, heavy-duty gasoline trucks, light-duty diesel vehicles, light-duty diesel trucks and heavy-duty diesel trucks. It was assumed that light-duty gas and diesel trucks have the same mass fractions as light-duty gas vehicles and diesel vehicles, respectively. For light duty gas vehicles and trucks, mass fractions were disaggregated for four different catalytic types for running emissions and two different fuel systems. Heavy-duty gas vehicles were assumed to have a carbureted fuel system with either no catalyst or three-way catalyst. These mass fractions were applied to TOG emission factors developed to calculate in-use toxics emission factors.

A number of important assumptions were made in the development of these in-use toxic emission factors. They include:

1. Increase in air toxics due to vehicle deterioration with increased mileage is proportional to increase in TOG.

2. Toxics fractions remain constant with ambient temperature changes.

3. The fractions are adequate to use for the excess hydrocarbons that come from malfunction and tampering/misfueling.

It should be noted that in specific situations, the EPA Mobile models may over or underestimate actual emissions.

The butadiene emission factors by vehicle class in grams of butadiene emitted per mile driven are shown in Table 6-1.[44] The OMS also performed multiple runs of the MOBTOX program to derive a pollutant-specific, composite emission factor that represented all vehicle classes, based on the percent of total vehicle miles traveled (VMT) attributable to each vehicle class. Table 6-1 also presents the composite emission factor in pounds (grams) of butadiene emitted per mile driven.[17]

TABLE 6-1. BUTADIENE EMISSION FACTORS FOR 1990
TAKING INTO CONSIDERATION VEHICLE AGING (g/mi)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	Weighted VMT Mix
Exhaust										
Areas with no I/M	0.017	0.026	0.042	0.029	0.087	0.007	0.011	0.057	0.029	0.024
Areas with basic I/M	0.013	0.026	0.042	0.029	0.087	0.007	0.011	0.057	0.029	0.022

Source: Reference 44.

LDGV = Light-Duty Gasoline Vehicle
LDGT1 = Light-Duty Gasoline Truck [pick-ups and vans with gross vehicle weight of 0 to 6000 lb (0 to 272 kg)]
LDGT2 = Light-Duty Gasoline Truck [pick-ups and vans with gross vehicle weight of 6001 to 8500 lb (273 to 3,856 kg)]
LDGT = Light-Duty Gasoline Truck (combined category of LDGT1 and LDGT2)
HDGV = Heavy-Duty Gasoline Vehicle
LDDV = Light-Duty Diesel Vehicle
LDDT = Light-Duty Diesel Truck
HDDV = Heavy-Duty Diesel Vehicle
MC = Motorcycle

The OMS continues to update the on-road mobile sources model. As of the date of preparation of this report, MOBILE5a was available, but butadiene-specific emission factors had not been generated. Emissions based on this newer model, however, are estimated to be about 20 percent higher on average than those from MOBTOX. Due to the higher VOC emission rates associated with the newer model, the emission rates for 1,3-butadiene may also be incrementally higher.

Use of methanol in motor vehicles will result in substantial 1,3-butadiene emission reductions. Projected reductions in butadiene levels of approximately 93 percent were given in a recent comparison of gasoline and 85-percent methanol (M85) emissions from flexible fuel and variable fuel vehicles.[45] Also, butadiene emissions reductions of 99 percent for optimized flexible fuel vehicles running on 100-percent methanol (M100) fuel were estimated in EPA's Methanol Special Report.[46] Substantial reductions in butadiene emissions are also expected with use of ethanol as a clean fuel.[47] Finally, butadiene emissions with the use of compressed natural gas are extremely low.[48,49]

6.2 OFF-ROAD MOBILE SOURCES

For off-road mobile sources, EPA prepared the 1991 report *Non-road Engine Vehicle Emission Study* (NEVES),[50] which presents emission factors for 79 equipment types, ranging from small equipment such as lawnmowers and chain saws, to large agricultural, industrial, and construction machinery (see Table 6-2). Locomotives, aircraft, and rockets are not included. The equipment types were evaluated based on three engine designs: 2-stroke gasoline, 4-stroke gasoline, and diesel. Sources for the data include earlier EPA studies and testing and new information supplied by the engine manufacturers for tailpipe exhaust and crankcase emission. For test data on new engines, adjustments were made to better represent emissions from in-use equipment because EPA believes the new engine data do not take into consideration increase in emissions due to engine deterioration associated with increased equipment age; therefore, new engine data underestimate in-use emissions.[50]

TABLE 6-2. OFF-ROAD EQUIPMENT TYPES AND BUTADIENE EMISSION FACTORS INCLUDED IN THE NEVES (g/hp-hr) (FACTOR QUALITY RATING E)

Equipment type, AMS Code (2-stroke gas/4-stroke gas/diesel)	2-Stroke Gasoline Engines: Exhaust	2-Stroke Gasoline Engines: Crank Case	4-Stroke Gasoline Engines: Exhaust	4-Stroke Gasoline Engines: Crank Case	Diesel Engines: Exhaust	Diesel Engines: Crank Case
Lawn and Garden, 22-60/65/70-004-						
025 Trimmers/Edgers/Brush Cutters	6.13[a]	N/A	0.66[a]	0.104[a]	N/A	N/A
010 Lawn Mowers	5.68[a]	N/A	1.03[a]	0.162[a]	N/A	N/A
030 Leaf Blowers/Vacuums	5.88[a]	N/A	0.53[a]	0.083[a]	N/A	N/A
040 Rear Engine Riding Mowers	N/A	N/A	0.25[a]	0.040[a]	0.02	N/A
045 Front Mowers	N/A	N/A	0.25[a]	0.040[a]	N/A	N/A
020 Chain Saws <4 hp	8.14[a]	N/A	N/A	N/A	N/A	N/A
050 Shredders <5 hp	5.68[a]	N/A	1.03[a]	0.162[a]	N/A	N/A
015 Tillers <5 hp	5.68[a]	N/A	1.03[a]	0.162[a]	N/A	N/A
055 Lawn and Garden Tractors	N/A	N/A	0.26[a]	0.040[a]	0.02	N/A
060 Wood Splitters	N/A	N/A	1.03[a]	0.162[a]	0.02	N/A
035 Snowblowers	5.68[a]	N/A	1.03[a]	0.162[a]	N/A	N/A
065 Chippers/Stump Grinders	N/A	N/A	0.74[b]	0.162[b]	0.02	N/A
070 Commercial Turf Equipment	5.68[a]	N/A	0.26[a]	0.040[a]	N/A	N/A
075 Other Lawn and Garden Equipment	5.68[a]	N/A	1.03[a]	0.162[a]	0.02	N/A
Airport Service, 22-60/65/70-008-						
005 Aircraft Support Equipment	N/A	N/A	0.13[b]	0.029[b]	0.03[c]	N/A[c]
010 Terminal Tractors	0.06[b,d]	0.013[b,d]	0.13[b]	0.029[b]	0.03[c]	N/A[c]
Recreational, 22-60/65/70-001-						
030 All Terrain Vehicles (ATVs)	16.38[a,e]	N/A	2.73[a,e]	0.429[a,e]	N/A	N/A
040 Minibikes	N/A	N/A	2.73[a,e]	0.429[a,e]	N/A	N/A
010 Off-Road Motorcycles	16.38[a,e]	N/A	1.95[b,e]	0.429[b,e]	N/A	N/A
050 Golf Carts	16.38[a,e]	N/A	2.73[a,e]	0.429[a,e]	N/A	N/A
020 Snowmobiles	2.98[a]	N/A	N/A	N/A	N/A	N/A
060 Specialty Vehicles Carts	16.38[a,e]	N/A	2.73[a,e]	0.429[a,e]	0.02[e]	N/A[e]

TABLE 6-2. CONTINUED

Equipment type, AMS Code (2-stroke gas/4-stroke gas/diesel)	2-Stroke Gasoline Engines Exhaust	2-Stroke Gasoline Engines Crank Case	4-Stroke Gasoline Engines Exhaust	4-Stroke Gasoline Engines Crank Case	Diesel Engines Exhaust	Diesel Engines Crank Case
Recreational Marine Vessels, 22-82-005/010/020-						
005 Vessels w/Inboard Engines	11.36[b,f]	N/A	1.41[b,f]	N/A	0.39[f]	N/A
010 Vessels w/Outboard Engines	11.36[b,f]	N/A	1.71[b,f]	0.376[b,f]	0.39[f]	0.008[f]
Vessels w/Sterndrive Engines	11.36[b,f]	N/A	1.41[b,f]	N/A	0.39[f]	N/A
020 Sailboat Auxiliary Inboard Engines	N/A	N/A	1.41[b,f]	N/A	1.96[f]	N/A
025 Sailboat Auxiliary Outboard Engines	11.36[b,f]	N/A	1.71[b,f]	0.376[b,f]	1.96[f]	0.039[f]
Light Commercial, less than 50 HP, 22-60/65/70-006-						
005 Generator Sets	5.68[a]	N/A	0.26[a]	0.041[a]	0.02	N/A
010 Pumps	0.12[a,d]	0.018[a,d]	0.26[a]	0.041[a]	0.02	N/A
015 Air Compressors	N/A	N/A	0.26[a]	0.041[a]	0.02	N/A
020 Gas Compressors	0.08[b,d]	0.018[b,d]	N/A	N/A	N/A	N/A
025 Welders	N/A	N/A	0.26[a]	0.041[a]	0.02	N/A
030 Pressure Washers	N/A	N/A	0.26[a]	0.041[a]	0.02	N/A
Industrial, 22-60/65/70-003-						
010 Aerial Lifts	0.06[b,d]	0.019[b,d]	0.13[b]	0.029[b]	0.03[c]	N/A[c]
102 Forklifts	0.06[b,d]	0.019[b,d]	0.13[b]	0.029[b]	0.03[c]	N/A[c]
030 Sweepers/Scrubbers	0.06[b,d]	0.019[b,d]	0.13[b]	0.029[b]	0.03[c]	N/A[c]
040 Other General Industrial Equipment	4.06[b]	N/A	0.13[b]	0.029[b]	0.03[c]	N/A[c]
050 Other Material Handling Equipment	N/A	N/A	0.13[b]	0.029[b]	0.03[c]	N/A[c]
Construction, 22-60/65/70-002-						
003 Asphalt Pavers	N/A	N/A	0.13[b]	0.028[b]	0.01	N/A
006 Tampers/Rammers	5.68[a]	N/A	0.18[a]	0.028[a]	0.00	0.00
009 Plate Compactors	5.68[a]	N/A	0.18[a]	0.028[a]	0.01	N/A
012 Concrete Pavers	N/A	N/A	N/A	N/A	0.02	N/A
015 Rollers	N/A	N/A	0.25[a]	0.040[a]	0.01	N/A
018 Scrapers	N/A	N/A	N/A	N/A	0.01[c]	N/A[c]
021 Paving Equipment	5.68[a]	N/A	0.18[a]	0.028[a]	0.02	N/A

TABLE 6-2. CONTINUED

Equipment type, AMS Code (2-stroke gas/4-stroke gas/diesel)	2-Stroke Gasoline Engines		4-Stroke Gasoline Engines		Diesel Engines	
	Exhaust	Crank Case	Exhaust	Crank Case	Exhaust	Crank Case
Construction, 22-60/65/70-002- (con't)						
024 Surfacing Equipment	N/A	N/A	0.18[a]	0.028[a]	0.00	0.00
027 Signal Boards	N/A	N/A	0.18[a]	0.028[a]	0.02	N/A
030 Trenchers	N/A	N/A	0.13[b]	0.028[b]	0.02[c]	N/A[c]
033 Bore/Drill Rigs	5.68[a]	N/A	0.13[b]	0.028[b]	0.02[c]	N/A[c]
036 Excavators	N/A	N/A	0.13[b]	0.028[b]	0.01[c]	N/A[c]
039 Concrete/Industrial Saws	N/A	N/A	0.18[a]	0.028[a]	0.02[c]	N/A[c]
042 Cement and Mortar Mixers	N/A	N/A	0.18[a]	0.028[a]	0.02	N/A
045 Cranes	N/A	N/A	0.13[b]	0.028[b]	0.02[c]	N/A[c]
048 Graders	N/A	N/A	N/A	N/A	0.02[c]	N/A[c]
051 Off-Highway Trucks	N/A	N/A	N/A	N/A	0.01[c]	N/A[c]
054 Crushing/Proc. Equipment	N/A	N/A	0.13[b]	0.028[b]	0.02[c]	N/A[c]
057 Rough Terrain Forklifts	N/A	N/A	0.13[b]	0.028[b]	0.03[c]	N/A[c]
060 Rubber Tire Loaders	N/A	N/A	0.11[b]	0.024[b]	0.01[c]	N/A[c]
063 Rubber Tire Dozers	N/A	N/A	N/A	N/A	0.01[c]	N/A[c]
066 Tractors/Loaders/Backhoes	N/A	N/A	0.13[b]	0.028[b]	0.02[c]	N/A[c]
069 Crawler Tractors	N/A	N/A	N/A	N/A	0.02[c]	N/A[c]
072 Skid Steer Loaders	N/A	N/A	0.13[b]	0.028[b]	0.03[c]	0.001[c]
075 Off-Highway Tractors	N/A	N/A	N/A	N/A	0.04[c]	0.001[c]
078 Dumpers/Tenders	N/A	N/A	0.18[a]	0.028[a]	0.01[c]	N/A[c]
081 Other Construction Equipment	N/A	N/A	0.13[b]	0.028[b]	0.02[c]	N/A[c]
Agricultural, 22-60/65/70-005-						
010 2-Wheel Tractors	N/A	N/A	0.15[a]	0.024[a]	N/A	N/A
015 Agricultural Tractors	N/A	N/A	0.11[b]	0.024[b]	0.04[c]	0.001[c]
030 Agricultural Mowers	N/A	N/A	0.20[a]	0.031[a]	N/A	N/A
020 Combines	N/A	N/A	0.14[b]	0.031[b]	0.02[c]	N/A[c]
035 Sprayers	N/A	N/A	0.14[b]	0.031[b]	0.04	0.001
025 Balers	N/A	N/A	N/A	N/A	0.04	0.001
040 Tillers >5 hp	N/A	N/A	1.03[a]	0.162[a]	0.02	N/A
045 Swathers	N/A	N/A	0.14[b]	0.031[b]	0.01	N/A
050 Hydro Power Units	N/A	N/A	0.20[a]	0.031[a]	0.04	0.001
055 Other Agricultural Equipment	N/A	N/A	0.14[b]	0.031[b]	0.03	0.001

TABLE 6-2. CONTINUED

Equipment type, AMS Code (2-stroke gas/4-stroke gas/diesel)	2-Stroke Gasoline Engines Exhaust	2-Stroke Gasoline Engines Crank Case	4-Stroke Gasoline Engines Exhaust	4-Stroke Gasoline Engines Crank Case	Diesel Engines Exhaust	Diesel Engines Crank Case
Logging, 22-60/65/70-007-						
005 Chain Saws >4 hp	4.15[a]	N/A	N/A	N/A	N/A	N/A
010 Shredders >5 hp	N/A	N/A	0.25[a]	0.040[a]	N/A	N/A
015 Skidders	N/A	N/A	N/A	N/A	0.01[c]	N/A[c]
020 Fellers/Bunchers	N/A	N/A	N/A	N/A	0.01[c]	N/A[c]

Source: Reference 50.

[a] Adjusted for in-use effects using small utility engine data.
[b] Adjusted for in-use effects using heavy duty engine data.
[c] Exhaust HC adjusted for transient speed and/or transient load operation.
[d] Emission factors for 4-stroke propane-fueled equipment.
[e] g/hr.
[f] g/gallon.
N/A = Not applicable.

Although these emission factors were intended for calculating criteria pollutant (VOCs, NO_x, CO) emissions for SIP emissions inventories, emission factors for several hazardous air pollutants (HAPs), including butadiene, were derived so that national air toxics emissions could be estimated. To estimate butadiene emissions, EPA expressed butadiene emissions as a weight percent of tailpipe exhaust hydrocarbons plus crank case hydrocarbons and combined the weight percents with existing hydrocarbon emission factors. The weight percents butadiene applied to all categories of equipment were 1.6 and 1.3 for diesel and gasoline engines, respectively. These are based on the recommendations from an EPA report *Non-road Emission Factors of Air Toxics*[51] that are based on automobile test data. For emissions from diesel-fueled marine vessels, high-speed, agricultural, construction and large utility equipment, the report suggests use of weight factors 1.5 percent for direct injection, and 1.7 percent for indirect injection diesel engines. For emissions from unleaded non-catalyst gasoline-powered marine vessels, agricultural, construction and large utility equipment, a 1.3 percent weight factor is recommended.[51] The NEVES distinguished between off-road diesel and gasoline engines and applied the diesel and gasoline weight percents to all equipment types. Future work may provide equipment-specific values and the use of these should be considered instead.

The most accurate emission estimate requires that the emission factors be used with local activity data. If these data are unavailable, a state may elect to approximate emissions using estimates from the NEVES for 24 nonattainment areas. Taking this approach, the state chooses one of the 24 nonattainment areas which best represents the state's offroad activity. The corresponding emission estimate is then adjusted by applying a ratio of the population for the two areas to more closely approximate the state's emissions. The NEVES report also provides estimates for counties in the 24 nonattainment areas; therefore, state and local agencies may prepare regional or county inventories by applying a population ratio to the NEVES estimates. For further details on the estimation procedure, the reader should refer to the NEVES report.

6.2.1 Marine Vessels

For commercial marine vessels, the NEVES report includes VOC emissions for six nonattainment areas taken from a 1991 EPA study *Commercial Marine Vessel Contribution to Emission Inventories*.[52] This study provided hydrocarbon emission factors for ocean-going commercial vessels and harbor and fishing vessels. The emission factors are shown in Table 6-3.

Ocean-going marine vessels fall into one of two categories--those with steam propulsion and those with motor propulsion. Furthermore, they emit pollution under two modes of operation: underway and at dockside (hotelling). Most steamships use boilers rather than auxiliary diesel engines while hotelling. Currently, there are no butadiene toxic emission fractions for steamship boiler burner emissions. The emission factors for motor propulsion systems are based on emission fractions for heavy-duty diesel vehicle engines. For auxiliary diesel generators, emission factors are available only for 500 KW engines, since the 1991 Booz-Allen and Hamilton[52] report indicated that almost all generators were rated at 500 KW or more.

For harbor and fishing vessels, butadiene emission factors for diesel engines are provided for the following horsepower categories -- less than 500 hp, 500 to 1,000 hp, 1,000 to

TABLE 6-3. BUTADIENE EMISSION FACTORS FOR COMMERCIAL MARINE VESSELS

Operating Plant (operating mode/rated output)	Butadiene Emission Factor (lb/1000 gal fuel)[a]
Ocean-Going Commercial	
Motor Propulsion	
All underway modes	0.38
Auxiliary Diesel Generators	
500 KW (50% load)	1.29
Harbor and Fishing	
Diesel Engines	
<500 hp	
Full	0.33
Cruise	0.81
Slow	0.90
500-1000 hp	
Full	0.38
Cruise	0.27
Slow	0.27
1000-1500 hp	
Full	0.38
Cruise	0.38
Slow	0.38
1500-2000 hp	
Full	0.27
Cruise	0.38
Slow	0.38
2000+ hp	
Full	0.34
Cruise	0.27
Slow	0.36
Gasoline Engines - all hp ratings	
Exhaust (g/bhp-hr)	0.04

Source: Reference 52.

[a] Butadiene exhaust emission factors were estimated by multiplying HC emission factors by butadiene TOG fractions. Butadiene exhaust emission fractions of HC for all marine diesel engines were assumed to be the same as the TOG emission fraction for heavy-duty diesel vehicles -- 0.0158. The butadiene exhaust emission fraction for marine gasoline engines was assumed to be the same as the exhaust TOG emission fraction for heavy duty gasoline vehicles -- 0.0057.

1,500 hp, 1,500 to 2,000 hp, and greater than 2,000 hp. In each of these categories, emission factors are developed for full, cruise, and slow operating modes. Butadiene emission factors are also provided for gasoline engines in this category. These emission factors are not broken down by horsepower rating, and are expressed in grams per brake horsepower hour rather than pounds per thousand gallons of fuel consumed.

6.2.2 Locomotives

As noted in the U.S. EPA's *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*,[53] locomotive activity can be defined as either line haul or yard activities. Line haul locomotives, which perform line haul operation, generally travel between distant locations, such as from one city to another. Yard locomotives, which perform yard operations, are primarily responsible for moving railcars within a particular railway yard.

The OMS has included locomotive emissions in its *Motor Vehicle-Related Air Toxic Study*.[17] The emission factors used for locomotives in this report are derived from the heavy-duty diesel on-road vehicles as there are no emission factors specifically for locomotives. To derive toxic emission factors for heavy duty diesel on-road vehicles, hydrocarbon emission factors were speciated. The emission factors provided in this study (shown in Table 6-4) are based on fuel consumption.[54]

6.2.3 Aircraft

There are two main types of aircraft engines in use: turbojet and piston. A kerosene-like jet fuel is used in the jet engines, whereas aviation gasoline with a lower vapor pressure than automotive gasoline is used for piston engines. The aircraft fleet in the United States numbers about 198,000, including civilian and military aircraft.[55] Most of the fleet is of the single- and twin-engine piston type and is used for general aviation. However, most of the

TABLE 6-4. BUTADIENE EMISSION FACTORS FOR LOCOMOTIVES

Source	Toxic Emission Fraction	Emission Factor (lb/gal)
Line Haul Locomotive	0.0158[a]	0.00033
Yard Locomotive	0.0158[a]	0.00080

Source: Reference 54.

[a] These fractions are found in Appendix B6 of Reference 55, and represent toxic emission fractions for heavy-duty diesel vehicles. Toxic fractions for locomotives are assumed to be the same, since no fractions specific for locomotives are available. It should be noted

fuel is consumed by commercial jets and military aircraft; thus, these types of aircraft contribute more to combustion emissions than does general aviation. Most commercial jets have two, three, or four engines. Military aircraft range from single or dual jet engines, as in fighters, to multi-engine transport aircraft with turbojet or turboprop engines.[56]

Despite the great diversity of aircraft types and engines, there are considerable data available to aid in calculating aircraft- and engine-specific hydrocarbon emissions, such as the database maintained by the Federal Aviation Administration (FAA) Office of Environment and Energy, FAA Aircraft Engine Emissions Database (FAEED).[57] These hydrocarbon emission factors may be used with weight percent factors of butadiene in hydrocarbon emissions to estimate butadiene emissions from this source. Butadiene weight percent factors in aircraft hydrocarbon emissions are listed in the EPA SPECIATE database[58] and are presented inTable 6-5.[59]

Current guidance from EPA for estimating hydrocarbon emissions from aircraft appears in *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources.*[60] The landing/takeoff (LTO) cycle is the basis for calculating aircraft emissions. The operating modes in an LTO cycle are: (1) approach, (2) taxi/idle in, (3) taxi/idle out, (4) takeoff, and (5) climbout. Emission rates by engine type and operating mode are given and require that the fleet be

TABLE 6-5. BUTADIENE CONTENT IN AIRCRAFT LANDING AND TAKEOFF EMISSIONS

SPECIATE Profile #	Description	AMS Code	Weight Percent Butadiene	Factor Quality
1097	Military Aircraft	22-75-001-000	1.89	B
1098	Commercial Aircraft	22-75-020-000	1.80	B
1099	General Aviation	22-75-050-000	1.57	C
	Pistons		0.98	C
	Turbines		1.57	C
1214	Composite of 6 engines burning JP-4 fuel at 75% power	22-75-001-000	3.85	C
1215	Composite of 6 engines burning JP-4 fuel at 30% power	22-75-001-000	1.00	C
1216	Composite of 6 engines burning JP-4 fuel across all powers	22-75-001-000	2.08	C
1217	Composite of 6 engines burning JP-4 fuel at idle power	22-75-001-000	2.20	C
1218	Composite - TF-39 engine burning JP-5 fuel across all powers	22-75-001-000	2.86	C
1219	Composite - CTM-56 engine burning JP-5 fuel across all powers	22-75-001-000	2.47	C
1220	Composite - J79 engine burning JP-4 fuel across all powers	22-75-001-000	2.01	C

Source: References 58 and 59.

characterized and the time in each of the operating modes determined. From this information, hydrocarbon emissions can be calculated for one LTO for each aircraft type in the fleet. To determine total hydrocarbon emissions from the fleet, the emissions from a single LTO for the aircraft type must be multiplied by the number of LTOs for each aircraft type. The weight percent factor for butadiene can be applied to the total hydrocarbon emissions to estimate the butadiene emissions.

The emission estimating method noted above is the preferred approach as it takes into consideration differences between new and old aircraft. If detailed aircraft information is unavailable, hydrocarbon emission indices for representative fleet mixes are provided in the emissions inventory guidance document *Procedures for Emissions Inventory Preparation, Volume IV: Mobile Sources*.[60] The hydrocarbon emission indices are 0.394 pounds per LTO (0.179 kg per LTO) for general aviation and 1.234 pounds per LTO (0.560 kg per LTO) for air taxis.

The butadiene fraction of the hydrocarbon total can be estimated by using the percent weight factors from SPECIATE. Because air taxis have larger engines and more of the fleet is equipped with turboprop and turbojet engines than is the general aviation fleet, the percent weight factor is somewhat different from the general aviation emission factor. To approximate a butadiene percent weight factor for air taxis, the commercial and general aviation percent weight factors were averaged (see Table 6-6).[58,60,61] 6.2.4

Rocket Engines

Butadiene has also been detected from rocket engines tested or used for space travel. Source testing of booster rocket engines using RP-1 (kerosene) and liquid oxygen have been completed at an engine test site. Tests for butadiene were taken for eight test runs sampling four locations within the plume envelope below the test stand. Results from these tests yielded a range of butadiene emission factors--0.0368 to 0.47 lbs/ton (0.0151 to 0.193 kg/Mg) of fuel combusted (factor quality rating C)--providing an average emission factor of 0.14 lb/ton

TABLE 6-6. BUTADIENE EMISSION FACTORS FOR GENERAL AVIATION AND AIR TAXIS[a]

Aircraft Type	1990 National LTOs[b]	Hydrocarbon Emission Indices[c]	Hydrocarbon Total in tons (Mg)	Butadiene Weight Percent[d]	Butadiene Emissions in tons (Mg)
General Aviation	19,584,898	0.394 lb/LTO	3,858 (3,472)	1.57	61 (55)
Air Taxis	4,418,836	1.234 lb/LTO	2,726 (2,454)	1.69	46 (42)

[a] From Federal Aviation Administration-Controlled Towers.
[b] Source: Reference 61.
[c] Source: Reference 60.
[d] Source: Reference 58.

(0.058 kg/Mg) of fuel combusted. It should be noted that booster fuel consumption is approximately five times that of sustainer rocket engines.[4,62]

SECTION 7.0
EMISSIONS FROM MISCELLANEOUS SOURCES OF BUTADIENE

This section provides an overview of the miscellaneous sources of butadiene emissions. These sources can be divided into the following categories: miscellaneous chemical production; secondary lead smelting; petroleum refining; combustion sources (biomass burning, scrap tire burning, and stationary internal combustion sources); and "other." With regard to the chemical production category, the major uses of butadiene were discussed in Section 5.0. Section 7.0 identifies the smaller consumers, which account for about 8 percent of butadiene use in the United States. Available details of the production process and associated emissions are provided, where known. Often these details are incomplete; therefore, readers should contact the facilities directly for the most accurate information.

The biomass burning and scrap tire burning categories are extremely diverse sources and are therefore difficult to quantify. This section describes the various types of burning and any associated emissions. The "other" category contains sources that have been identified as possible butadiene sources, but for which specific emissions data are lacking.

7.1 MISCELLANEOUS USES OF BUTADIENE IN CHEMICAL PRODUCTION

Eighteen companies at 19 locations are producing 14 different products from butadiene. Originally identified in a summary report on miscellaneous butadiene uses,[35] this list of facilities has been updated using the *1993 Directory of Chemical Producers - U.S.A.* These facilities are summarized in Table 7-1, along with estimated capacities.[19,29] Because data corresponding to each location are not readily available, all the production process descriptions, current as of 1984, appear first, followed by a summary of any emissions estimates.

7.1.1 Product and Process Descriptions

Styrene-Butadiene-Vinylpyridine (SBV) Latex

No information on the production process or the use of styrene-butadiene-vinylpyridine latex is available. As a copolymer, its production process is likely to be similar to that of other copolymers.

Tetrahydrophthalic (THP) Anhydride and Acid

Tetrahydrophthalic anhydride and acid (the acid is the hydrate form of the chemical) may be used either as a curing agent for epoxy resins or as an intermediate in the manufacture of Captan®, an agricultural fungicide.

In the manufacture of the anhydride as a curing agent, Mobay Synthetics (formerly Denka) is reported to use the following process. Liquid butadiene is first pressure-fed to a vaporizer. The resulting vapor is then pressure-fed to the reactor, where reaction with molten maleic anhydride occurs. Maleic anhydride is consumed over a period of 6 to 10 hours. The product, molten THP anhydride, is crystallized onto a chill roller at the bagging operation. Solidified anhydride is cut from the roller by a doctor blade into a weighed container, either a bag or drum.[63] Because ArChem also uses THP anhydride in epoxy resins, use of a process similar to Mobay Synthetics' was assumed.[35]

ICI American Holdings, Inc. (formerly Calhio) was reported to generate the anhydride for captive use as an intermediate for Captan®. In the generation process, butadiene is charged to reactors along with maleic anhydride to produce THP anhydride. The reaction is a Diels-Alder reaction, run under moderate temperature and pressure.[64]

TABLE 7-1. MISCELLANEOUS USES OF BUTADIENE IN CHEMICAL PRODUCTION

Company	Location	Product	Mode of Operation	Capacity in 1993 tons/yr (Mg/yr)
Ameripol Synpol	Port Neches, TX	Styrene-butadiene-vinylpyridine (SBV) Latex	Unknown	___
ArChem Company	Houston, TX	Tetrahydrophthalic (THP) Anhydride	Batch	572 (515)
B. F. Goodrich Company	Akron, OH	Butadiene-vinylpyridine Latex	Batch (on demand)	___
ICI American Holdings, Inc.	Perry, OH	Captan®	Batch	___
Chevron Chemical	Richmond, CA	Captafol®	Continuous	___
DuPont	Beaumont, TX	1,4-Hexadiene	Continuous	----
DuPont	Victoria, TX	Dodecanedioic Acid	Continuous (2 weeks per month due to low demand)	----
		Butadiene Dimers	Unknown	___
Dixie Chemical Company	Bayport, TX	THP Anhydride	Unknown	___
GenCorp	Mogadore, OH	SBV Latex	Unknown	___
Goodrich	Akron, OH	SBV Latex	Unknown	___
Goodyear	Calhoun, GA	SBV Latex	Unknown	___
Kaneka Texas Corporation	Bayport, TX	Methyl Methacrylate-butadiene-styrene (MBS) Resins	Batch	25,600 (23,000)
Metco America	Axis, AL	MBS Resins	Unknown	20,000 (18,000)

(continued)

TABLE 7-1. CONTINUED

Company	Location	Product	Mode of Operation	Capacity in 1993 tons/yr (Mg/yr)
Mobay Synthetics Corporation[a]	Houston, TX	THP Acid	Batch	1,700 (1,500)
Phillips Chemical Company	Borger, TX	Butadiene Cylinders[b]	Batch	539 (485)
		Butadiene-furfural Cotrimer[b]	Continuous, intermittent, about 65% of the time	50 (45)
		Sulfolane	Batch	___
Rohm and Haas Company	Louisville, KY	MBS Resins	Batch	25,500 (23,000)
Shell Oil Company	Norco, LA	Sulfolane	Unknown	___
Standard Oil Chemical Company	Lima, OH	Methyl Methacrylate-acrylonitrile-butadiene-styrene (MABS) Polymer	Unknown	___
Union Carbide	Institute, WV	Butadiene Dimers	Continuous	7,200 (6,500)
		Ethylidene Norbornene	Continuous	___

Source: References 19 and 29.

[a] Formerly Denka.
[b] Process in operation in 1984, status unknown in 1994.

"___" means capacity not known.
"----" means company-confidential.

Butadiene-Vinylpyridine Latex

Butadiene-vinylpyridine latex is produced at the B. F. Goodrich, Akron, Ohio, facility as an ingredient in an adhesive promoter. As a copolymer, the production process is similar to that of other copolymers, usually involving an emulsion polymerization process.[65] B. F. Goodrich operates the process in a batch mode, on a schedule that depends on demand.

The finished latex is blended with SB latex and a phenol-formaldehyde mixture to form a "dip" or an adhesive promoter. Dip is used with fabrics in geared rubber goods manufacturing. This includes fabric used in tires, hoses, and belting production.[66]

Methyl Methacrylate-Butadiene-Styrene Terpolymers

Methyl methacrylate-butadiene-styrene (MBS) terpolymers are produced in resin form by four companies at four locations. This resin is used as an impact modifier in rigid polyvinyl chloride products for applications in packaging, building, and construction.[35]

Production of MBS terpolymers is achieved using an emulsion process in which methyl methacrylate and styrene are grafted onto an SB rubber. The product is a two-phase polymer.[66]

Captan®

In Captan® production, tetrahydrophthalic anhydride is passed through an ammonia scrubber to produce tetrahydrophthalimide (THPI). Molten THPI is coated onto a chill roller, where it solidifies into a quasi-crystalline state. THPI is then conveyed into a reactor containing perchloromethyl mercaptan (PMM). Caustic is charged to the reactor, initiating the reaction that produces Captan®. Captan® is brought to a higher temperature in the heat treatment tank to remove residual PMM, after which the material passes through a vacuum filter to remove salt and water. The product cake is dried and collected in a baghouse.[64]

Captafol®

Chevron produces Captafol®, a fungicide, under the trade name Difolatan® at its Richmond, California, facility. The only information on the process is that production occurs on a continuous basis and is carried out in a pressurized system vented to an incinerator.[35]

1,4-Hexadiene

DuPont produces 1,4-hexadiene for use in manufacturing Nordel® synthetic rubber. Nordel® polymer is used in the manufacture of rubber goods, wire and cable insulation, automobile bumpers, and as an oil additive.[67]

In the reactor, butadiene reacts with ethylene to form 1,4-hexadiene. After reaction, unreacted 1,3-butadiene and ethylene, along with 1,4-hexadiene and by-products, are flashed from the catalyst and solvent. The maximum temperature in the process is approximately 250°F (121°C). The catalyst solution is pumped back to the reactor; vaporized components are sent to a stripper column. The column separates ethylene and 1,3-butadiene from the 1,4-hexadiene product and by-products; unreacted components are pumped back to the reactor. The 1,4-hexadiene and by-products are sent to crude product storage before transfer to refining. The 1,4-hexadiene is refined in low-boiler and high-boiler removal columns and transferred to the Nordel® polymerization process.[68]

Dodecanedioic Acid

Dodecanedioic acid (DDDA) is produced by DuPont for use as an intermediate in the production of 1,5,9-cyclodecatriene, a constituent in the manufacture of DuPont's Quiana® fabric.[68] Butadiene can be converted into several different cyclic or open-chain dimers and trimers, depending upon the reaction conditions and catalysts. Although vinylcyclohexene and

1,5-cyclooctadiene are the predominant products, 1,2-divinylcyclobutane may be formed under suitable reaction conditions. Nickel catalysts are often used in the cyclodimerization and cyclotrimerization of butadiene; however, complexes of iron, copper (I), zeolite, and compositions also promote cyclodimerization, often giving cyclooctadiene as the principal product.[68]

Butadiene Cylinders

Phillips Chemical Company fills cylinders with butadiene monomer at its Borger, Texas, facility. A NIOSH survey report on this facility indicates that these cylinders may be samples of butadiene taken for process quality control.[69] The report describes routine quality control sampling in the tank farm area in which the samples are collected using pressure cylinders. Operators connect the sample containers to a process line and open valves to fill the cylinder. Butadiene fills the container and is purged out of the rear of the cylinder before the valve is closed, resulting in emissions from the cylinder. The sample container is subjected to vacuum exhaust under a laboratory hood at the conclusion of sampling.[35]

Butadiene Furfural Cotrimer

Butadiene furfural cotrimer or 2,3,4,5-bis(butadiene)tetrahydrofurfural, commonly known as R-11, is used as an insect repellant and as a delousing agent for cows in the dairy industry. The concentrations of R-11 in commercial insecticide spray are generally less than 1 percent.[69]

Production of R-11 at Phillips' Borger, Texas, facility, occurs intermittently throughout the year; however, when operating, the production process is a continuous operation. In the process, butadiene reacts with an excess of furfural in a liquid-phase reactor. The reaction proceeds under moderate conditions of temperature and pressure and consumes 1 mole of furfural for 2 moles of butadiene. After a period of 4 to 5 hours, the reaction mixture is transferred to the reactor effluent surge tank. The mixture proceeds to a vertical column that separates butadiene dimer by distillation. Butadiene dimer, or 4-vinyl-1-cyclohexane, is recovered from the column and later transported to a refinery for reprocessing in crude catalytic cracking units.[69]

Furfural is removed from the reaction products by distillation in a similar column and recycled to the reactor. The last column in the R-11 process runs as a batch operation, and separates R-11 from the polymer kettle product. The kettle product is a crystalline solid that is disposed of in an on-site landfill. R-11, which is in the form of a yellow liquid, is transferred to storage tanks and shipped to customers in drums.[69]

Sulfolane

Sulfolane is a common trade name for tetrahydrothiophene 1,1-dioxide. It is used principally as a solvent for extracting aromatic hydrocarbons from mixtures containing straight-chained hydrocarbons. Sulfolane is produced by first reacting butadiene and sulfur dioxide to form 3-sulfolene. The 3-sulfolene is then hydrogenated to produce sulfolane. Phillips' Borger, Texas, facility is assumed to be using a similar process. The Shell facility at Norco, Louisiana, has a sulfolane production unit downstream of the butadiene recovery process that is included as part of the butadiene production facility.[19]

Methyl Methacrylate-Acrylonitrile-Butadiene-Styrene (MABS) Polymers

MABS polymers are produced by Standard Oil Company under the trade name Barex®. The MABS copolymers are prepared by dissolving or dispersing polybutadiene rubber in a mixture of methyl methacrylate-acrylonitrile-styrene and butadiene monomer. The graft copolymerization is carried out by a bulk or a suspension process. The final polymer is two-phase, with the continuous phase terpolymer of methyl methacrylate, acrylonitrile, and styrene grafted onto the dispersed polybutadiene phase.[66]

These polymers are used in the plastics industry in applications requiring a tough, transparent, highly impact-resistant, and thermally-formable material. Except for their transparency, the MABS polymers are similar to the opaque ABS plastics. The primary function of methyl methacrylate is to match the refractive indices of the two phases, thereby imparting transparency.[66]

Butadiene Dimers

Tetrahydrobenzaldehyde (THBA), a butadiene dimer, is produced by Union Carbide and DuPont (Victoria, Texas). At Union Carbide, butadiene is reacted with acrolein and cyclohexane to produce THB anhydride in +90-percent yields over a short period of time when the reaction is carried out at temperatures up to 392°F (200°C).[68] The reaction will also take place at room temperature in the presence of an aluminum-titanium catalyst. A by-product of the reaction is 4-vinyl-1-cyclohexane.[68] At the Union Carbide facility, THBA is recovered and the unreacted raw materials are recycled to the feed pot. The feed pot, reactor, recovery stills, and refined product storage tanks are all vented to a flare header.[35] In the absence of process information at the DuPont facility, it is assumed to be using a similar production process.

Ethylidene Norbornene (ENB)

ENB, produced by Union Carbide, is a diene that is used as a third monomer in the production of ethylene-propylene-dimethacrylates. Ethylene-propylene-dimethacrylate elastomers are unique in that they are always unsaturated in the side chain pendant to the main or backbone chain. Therefore, any oxidation or chemical reaction with residual unsaturation has only a limited effect on the properties of the elastomer.[70]

7.1.2 Emissions

No emissions data are available for the following products: SBV latex, Captan®, Captafol®, THP acid, and ethylidene norbornene. For processes where emissions information is available, it is limited to three sources: process vents, equipment leaks, and secondary sources.[19,35] Butadiene emissions from raw material storage are expected to be negligible because butadiene is usually stored under pressure. Some emissions resulting from accidental and emergency releases and transfer and handling of raw materials are likely; however, they have not generally been quantified.

Data are available for process vent emissions from production processes at eight facilities. At five of these facilities, flares or boilers are used on some vents to control emissions. At a sixth facility, emissions reduction is achieved by recovery of the vented stream off the butadiene-furfural cotrimer process, one of the two process vents identified. Because every facility did not report an emissions estimate for each process vent listed, emissions data are incomplete.

The emission factors for process vents and secondary sources are summarized in Table 7-2,[19,35,65] with facility-specific data appearing in Tables C-23 through C-25 in Appendix C. Ranges are provided if more than one data point was available. The facility emission factors include the control that each facility providing the data has in place. The uncontrolled emission factors represent potential emissions if controls were not in use.

Because equipment count data were not readily available, no calculations of equipment leak emissions using average CMA factors were done. Instead, equipment leak estimates for eight processes at eight facilities were taken from memoranda prepared for EPA in 1986.[19,35] Because information on emissions control through leak detection and repair programs was incomplete, adjustments to estimated emissions could not be made. The only other controls in use were double mechanical pump seals and rupture discs on pressure relief devices.

Based on information on secondary sources from eight facilities, emissions generally appear to be negligible from these sources, despite different end products. One exception is the butadiene-vinylpyridine process. The facility estimated butadiene emissions from wastewater volatilization to be approximately 1.3 tons/yr (1.2 Mg/yr).[65]

Two estimates for emergency vent releases during upsets, startups, and shutdowns of the 1,4-hexadiene process are 0.2 tons/yr (0.2 Mg/yr) (uncontrolled) off the abatement collection system for waste liquid and vapors and 47.5 tons/yr (43.1 Mg/yr) from the reactor

TABLE 7-2. SUMMARY OF EMISSION FACTORS AND ANNUAL EMISSIONSFROM EQUIPMENT LEAKS FOR MISCELLANEOUS CHEMICALSPRODUCTIONFACILITIES[a,b]
(FACTOR QUALITY RATING U)

Chemical Produced	Source	Facility Emission Factors		Uncontrolled Emission Factors	
Butadiene Cylinders 3-01-153	Process Vents	43.2 lb/ton	(21.6 kg/Mg)	43.2 lb/ton	(21.6 kg/Mg)
	Equipment Leaks	<0.11 tons/yr	(<0.1 Mg/yr)	<0.11 tons/yr	(<0.1 Mg/yr)
	Secondary Sources	NA		NA	
Butadiene Dimers 3-01	Process Vents	0.030 lb/ton	(0.015 kg/Mg)	1.54 lb/ton	(0.77 kg/Mg)
	Equipment Leaks	4.3 tons/yr	(3.9 Mg/yr)	---	
	Secondary Sources	0		0	
Butadiene-furfural Cotrimers 3-01	Process Vents	440 lb/ton	(220 kg/Mg)	440 lb/ton	(220 kg/Mg)
	Equipment Leaks	1.1 tons/yr	(0.5 Mg/yr)	---	
	Secondary Sources	0		0	
Butadiene-vinylpyridine Latex 3-01-026	Process Vents	---		---	
	Equipment Leaks	0.61 tons/yr	(0.55 Mg/yr)	NA	
	Secondary Sources (Wastewater)	NA		---	
Dodecanedioic Acid 6-84-350	Process Vents	---		---	
	Equipment Leaks	5.73 tons/yr	(5.2 Mg/yr)	5.73 tons/yr	(5.2 Mg/yr)
	Secondary Sources	NA		NA	
1,4-Hexadiene 3-01	Process Vents	---		---	
	Equipment Leaks	59.3 tons/yr	(53.8 Mg/yr)	67.7 tons/yr	(61.4 Mg/yr)
	Secondary Sources	0		0	

(Continued)

TABLE 7-2. Continued

Chemical Produced	Source	Facility Emission Factors		Uncontrolled Emission Factors	
Methylmethacrylate-butadiene-styrene Resins 6-41	Process Vents	1.8 lb/ton	(0.9 kg/Mg)	17.2 lb/ton	(8.6 kg/Mg)
	Equipment Leaks	4.0 - 17.4 tons/yr (n=2)	(3.6 - 15.8 Mg/yr)[c]	17.4 tons/yr (n=2)	(15.8 Mg/yr)
	Secondary Sources	0 (n=2)		0 (n=2)	
Sulfolane 3-01	Process Vents	---		---	
	Equipment Leaks	1.8 - 14.7 tons/yr (n=2)	(1.6 - 13.3 Mg/yr)[c]	1.8 - 14.7 tons/yr[c] (n=2)	(1.6 - 13.3 Mg/yr)[c]
	Secondary Sources	NA		NA	
Tetrahydrophthalic Anhydride/Acid 3-01	Process Vents	---		---	
	Equipment Leaks	2.4 tons/yr	(2.2 Mg/yr)	2.4 tons/yr	(2.2 Mg/yr)
	Secondary Sources	0 (n=2)		0 (n=2)	

Source: References 19, 35, and 65.

[a] Assumes production capacity of 100 percent.
[b] Factors are expressed as lb (kg) butadiene emitted per ton (Mg) produced and tons (Mg) emitted per year.
[c] Range is based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.

NA = not available.
"---" means not calculated because production capacity was not available.

emergency vent. A brine refrigerated condenser on the reactor emergency vent may afford some emissions reduction, but an efficiency was not indicated.[35]

7.2 INDIRECT SOURCES OF BUTADIENE

A number of indirect sources of butadiene emissions have been identified. Each is described briefly below. Where emissions information was available, this is also provided. Because of EPA's increasing interest in air toxics, emissions information may be available in the future; therefore, the reader should consider a literature search to identify new sources of butadiene and locate emissions data.

7.2.1 Vinyl Chloride Monomer and Polyvinyl Chloride Production

In vinyl chloride monomer (VCM) production, butadiene appears as an impurity in the final product at a maximum level of 6.0 ppm.[71] An emission factor developed for overall production of polyvinyl chloride (PVC) (SCC 6-46-300-01) at a representative PVC plant was calculated and is given as 4.6×10^{-4} lb/ton (2.1×10^{-4} g/kg) PVC produced.

7.2.2 Publicly Owned Treatment Works

Some estimates for emissions from wastewater sent to publicly owned treatment works (POTWs) by SB copolymer producers, considered a secondary source, were made based on three industry responses to EPA Section 114 requests.[72] Using data on the butadiene content of wastewater sent to a POTW for each of these facilities and air emission models developed by EPA's Office of Air Quality Planning and Standards (OAQPS) for treatment, storage, and disposal facilities, estimated emissions for all three facilities are 21 tons/yr (19 Mg/yr). This approach did not account for volatilization from wastewater during transport to the POTW.

An emission factor developed for butadiene in influent in a representative POTW was calculated and is given as 1.7×10^{3} lb/ton (771 g/kg) butadiene in influent.[4,72]

7.2.3 Secondary Lead Smelting

Although not a significant source, secondary lead smelters are a source of 1,3-butadiene emissions. The secondary lead smelting industry produces elemental and lead alloys by reclaiming lead mainly from scrap automobile batteries. There are approximately 23 secondary lead smelters in the United States.[73]

Lead-acid batteries represent about 90 percent of the raw materials at a typical secondary lead smelter.[73] A typical automotive lead-acid battery is made up of lead, sulfuric acid electrolyte, plastic separators, and a plastic casing. Older batteries may have a hard rubber casing instead of plastic. The plastic battery separators and hard rubber casings on older batteries are the sources of butadiene emissions from secondary lead smelting.

The secondary lead smelting process consists of (1) breaking lead-acid batteries and separating the lead-bearing materials from the other materials (including plastic and acid electrolyte); (2) melting lead metal and reducing lead compounds to lead metal in the smelting furnace (reverberatory, blast, rotary, or electric); and (3) refining and alloying the lead to customer specifications.[73]

The vast majority of butadiene emissions come from the smelting furnace process. Because of the lower exhaust temperature from the charge column, blast furnaces are substantially greater sources of organic HAP (including butadiene) and related emissions than are reverberatory or rotary furnaces. From uncontrolled concentrations of butadiene measured during testing of a blast furnace outlet, an average emission factor of 1.16 lb/ton, range 0.78 - 1.54 lb/ton (0.48 kg/Mg, range 0.32 - 0.63 kg/Mg) was developed.[73] For the rotary furnace, the calculated emission factor was 0.13 lb/ton (0.05 kg/Mg).

On June 23, 1995, EPA promulgated a NESHAP for the secondary lead production industry. The regulation rquires a reduction of hazardous air pollutant emissions from blast furnaces which will include butadiene emissions. All the requirements are to be implemented by June 1997. Users of this document should review the requirements to determine what the emission reductions are.

7.2.4 Petroleum Refining

According to 1992 Toxic Release Inventory (TRI) data, petroleum refineries are the fourth largest emitters of butadiene following the production of organic chemicals, synthetic rubber, and plastics and resins.[74] However, besides the TRI figure of 437,590 lb/yr (397,000 Mg/yr) of butadiene emitted, no other emissions numbers were located. The Petroleum Refineries NESHAP was promulgated on August 18, 1995. Information Collection Request (ICR) questionnaires supporting that work reported that butadiene is released from blowdown vents, catalyst regeneration process vents, and miscellaneous vents at vacuum distillation, alkylation, and thermal cracking units.[75] However, Clean Air Act Section 114 questionnaires for that NESHAP did not require the reporting of butadiene emissions. For equipment leaks, EPA has prepared average emission rates. These are provided in Appendix D along with a description of equipment leak estimation methods.

Requirements of this NESHAP and the earlier Benzene NESHAP will reduce butadiene emissions by an estimated 60 percent, assuming reductions are similar to those for HAPs and VOCs overall. However, the reader is referred to the regulations to evaluate the exact impact at a particular facility.

7.2.5 Combustion Sources

Butadiene is produced in the combustion of diverse materials such as gasoline, diesel oil, wood, and tobacco. Therefore, all combustion processes are potential sources of butadiene. A brief description of biomass burning, tire burning, and stationary internal combustion sources and their potential butadiene emissions follow.

Biomass Burning

Fires are known to produce respirable particulate matter and toxic substances. Concern has even been voiced regarding the effect of emissions from biomass burning on climate change.[76] Burning wood, leaves, and vegetation can be a source of butadiene emissions. In this document, the burning of any wood, leaves, and vegetation is categorized as biomass burning, and includes yard waste burning, land clearing/burning and slash burning, and forest fires/prescribed burning.[77]

Part of the complexity of fires as a source of emissions results from the complex chemical composition of the fuel source. Different woods and vegetation are composed of varying amounts of cellulose, lignin, and extractives such as tannins, and other polyphenolics, oils, fats, resins, waxes, and starches.[78] General fuel type categories in the National Fire-Danger Rating (NFDR) System include grasses, brush, timber, and slash (residue that remains on a site after timber harvesting).[78] The flammability of these fuel types depends upon plant species, moisture content, whether the plant is alive at the time of burning, weather, and seasonal variations.

Pollutants from the combustion of biomass include carbon monoxide (CO), nitrogen oxides, sulfur oxides, oxidants, polycyclic organic matter, hydrocarbons, and particulate matter. The large number of combustion products is due, in part, to the diversity of combustion processes occurring simultaneously within fire--flaming, smoldering, and glowing combustion. These processes are distinct combustion processes that involve different chemical reactions that affect when and what pollutants will be emitted during burning.[78]

Emission factor models based on field and laboratory data were developed by the U.S. Forest Service. These models incorporate variables such as fuel type and combustion types (flaming or smoldering). Because air toxic substances are correlated with the release of other primary products of incomplete combustion [CO and carbon dioxide (CO_2)], the models correlate butadiene with CO emissions.[78] These emission factor models were used to develop emission factors for the biomass burning sub-categories described in the following sections.[77]

TABLE 7-3. EMISSION FACTORS FOR 1,3-BUTADIENE FOR BURNING OF YARD WASTE, LAND CLEARING/BURNING, AND SLASH BURNING (FACTOR QUALITY RATING U)

Yard Waste (AMS 26-10-030-000)	Land Clearing/Burning (AMS 28-01-500-000)	Slash (pile) Burning (AMS 28-10-005-000)
0.40 lb/ton	0.32 lb/ton	0.32 lb/ton
(0.198 g/kg)	(0.163 g/kg)	(0.163 g/kg)

Source: References 77 and 78.

Because of the potential variety in the fuel source and the limited availability of emission factors to match all possible fuel sources, emission estimates may not necessarily represent the combustion practices occurring at every location in the United States. Therefore, localized practices of such parameters as type of wood being burned and control strategies should be carefully compared.[77]

Yard Waste Burning--Yard waste burning is the open burning of such materials as landscape refuse, wood refuse, and leaves in urban, suburban, and residential areas.[77] Yard waste is often burned in open drums, piles, or baskets located in yards or fields. Ground-level open burning emissions are affected by many variables, including wind, ambient temperature, composition and moisture content of the material burned, and compactness of the pile. It should be noted that this type of outdoor burning has been banned in certain areas of the United States, thereby reducing emissions from this subcategory.[77,79] An emission factor for yard waste is shown in Table 7-3.[77,78]

Land Clearing and Slash Burning--This subcategory includes the burning of organic refuse (field crops, wood, and leaves) in fields (agricultural burning) and wooded areas (slash burning) in order to clear the land. Burning as part of commercial land clearing often requires a permit.[77] Emissions from organic agricultural refuse burning are dependent primarily on the moisture content of the refuse and, in the case of field crops, on whether the refuse is burned in a headfire or a backfire.[79] Other variables, such as fuel loading (how much refuse material is burned per unit of land area) and how the refuse is arranged (in piles, rows, or spread out), are also important in certain instances. Emission factors for land clearing/burning and slash burning are shown in Table 7-3.[77,78]

Forest Fires/Prescribed Burning--A forest fire (or wildfire) is a large-scale natural combustion process that consumes various ages, sizes, and types of outdoor vegetation.[80] The size, intensity, and even occurrence of a forest fire depend on such variables as meteorological conditions, the species and moisture content of vegetation involved, and the weight of consumable fuel per acre (fuel loading).[80]

Prescribed or broadcast burning is the intentional burning of forest acres as part of forest management practices to achieve specific wildland management objectives. Controlled burning can be used to reduce fire hazard, encourage wildlife habitat, control insects, and enhance the vigor of the ecosystem.[78] Prescribed burning occurs thousands of times annually in the United States, and individual fires vary in size from a fraction of an acre to several thousand acres. Prescribed fire use is often seasonal, which can greatly affect the quantity of emissions produced.[78]

HAP emission factors for forest fires and prescribed burning were developed using the same basic approach as for yard waste and land clearing burning, with an additional step to further classify fuel types into woody fuels (branches, logs, stumps, and limbs), live vegetation, and duff (layers of partially decomposed organic matter).[77] In addition to the fuel type, the methodology was altered to account for different phases of burning, namely, flaming and smoldering.[77] The resulting emission factors are shown in Table 7-4.[77,78]

TABLE 7-4. EMISSION FACTORS FOR 1,3-BUTADIENE FOR FOREST FIRES AND PRESCRIBED BURNING BY FUEL TYPE
(FACTOR QUALITY RATING U)

Fuel Type	Forest Fires (AMS 28-10-001-000) lb/ton (g/kg)	Prescribed Burning (Broadcast) (AMS 28-10-015-000) lb/ton (g/kg)
Fine wood	0.24 (0.12)	0.24 (0.12)
Small wood	0.24 (0.12)	0.24 (0.12)
Large wood (flaming)	0.24 (0.12)	0.24 (0.12)
Large wood (smoldering)	0.90 (0.45)	0.90 (0.45)
Live vegetation	0.52 (0.26)	0.52 (0.26)
Duff (flaming)	0.24 (0.12)	0.24 (0.12)
Duff (smoldering)	0.90 (0.45)	0.90 (0.45)

Source: References 77 and 78.

Tire Burning

Approximately 240 million vehicle tires are discarded annually.[81] Although viable methods for recycling exist, less than 25 percent of discarded tires are recycled; the remaining 175 million are discarded in landfills, stockpiles, or illegal dumps.[81] Although it is illegal in many states to dispose of tires using open burning, fires often occur at tire stockpiles and through illegal burning activities.[79] These fires generate a huge amount of heat and are difficult to extinguish (some tire fires continue for months). Butadiene is a major constituent of the tire fabrication process and is, therefore, present in emissions from tire burning.

Table 7-5 contains emission factors for chunk tires and shredded tires.[79,81] When estimating emissions from an accidental tire fire, it should be kept in mind that emissions from burning tires are generally dependent on the burn rate of the tire. A greater potential for emissions exists at lower burn rates, such as when a tire is smoldering rather than burning out of control.[79] The fact that the shredded tires have a lower burn rate indicates that the gaps between

TABLE 7-5. EMISSION FACTORS FOR 1,3-BUTADIENE FROM OPEN BURNING OF TIRES (SCC 5-03-002-03)[a,b] (FACTOR QUALITY RATING C)

Chunk Tires	Shredded Tires
234.28 lb/1000 tons (117.14 mg/kg)	277.95 lb/1000 tons (138.97 mg/kg)

Source: References 79 and 81.

[a] Values are weighted averages because of differing burn rates.
[b] Emissions determined using system response to toluene. Data averaged over six sets of VOST tubes per day taken over 2 days.

tire materials provide the major avenue of oxygen transport. Oxygen transport appears to be a major, if not the controlling mechanism for sustaining the combustion process.[81]

Besides accidental or illegal open burning of tires, waste tires are incinerated for energy recovery and disposal purposes. Tires are combusted at tire-to-energy facilities, cement kilns, tire manufacturing facilities, and as supplemental fuel in boilers, especially in the pulp and paper industry. No emission factors for butadiene from tire incineration have been located.

Other Stationary Combustion Sources

Because butadiene has been detected from mobile combustion sources and biomass and tire burning, stationary external and internal combustion sources are potential sources as well. External combustion sources include utility boilers and residential wood combustion. No emission factors were identified for these sources. Internal combustion sources include gasoline and diesel engines used for industrial and commercial activities, as well as gas turbines applied in electric power generation. Available emissions information is summarized below.

Gasoline and diesel internal combustion engines are used in aerial lifts, fork lifts, mobile refrigeration units, generators, pumps, industrial sweepers/scrubbers, and material handling equipment (such as conveyors). The rated power of these engines covers a substantial range, up to 250 hp (186 kW) for gasoline engines and up to 600 hp (445 kW) for diesel engines. These have been included in the off-road sources in Section 6.0. Diesel engines larger than 600 hp (445 kW) are used primarily in oil and gas exploration and production, supplying mechanical power to operate drilling, mud pumping, and hoisting equipment generators. These larger diesel engines are frequently used for electrical generation, irrigation, and nuclear power plant emergency cooling water pump operations.[82]

Even though butadiene emissions have been quantified for both gasoline and diesel mobile combustion engines, butadiene emission factors for stationary internal combustion engines have only been developed for uncontrolled diesel engines (SCCs 2-02-001-02 and 2-03-001-01, industrial and commercial/institutional reciprocating IC engines, respectively, fueled with either distillate oil or diesel). The current emission factor provided in the fifth edition of AP-42 is <0.0000391 lbs/MMBtu of fuel (<0.017 ng/J of fuel). This emission factor is rated E due to a limited data set (one diesel engine), and/or a lack of documentation of test results. Such an emission factor may not be suitable for estimating emissions from specific facilities and should be used with care.[82]

Gas turbines greater than 3 MW are primarily used in electrical generation for continuous, peaking, or standby power. They are also used as gas pipeline pumps, compressor drivers, and in various process industries. This diversity of uses has lead to the development of a diversity of engine designs and models using a wide range of fuels, including natural gas, distillate (No. 2) fuel oil, and in a few cases, residual fuel oil. Although butadiene emissions from gas turbines are presently being investigated, there are currently no emission factors to quantify butadiene emissions.[82]

7.3 OTHER BUTADIENE SOURCES

Other potential sources of butadiene emissions have been identified by OAQPS, which has collected information to assist State and local agencies in their toxic air pollutant programs. The Crosswalk/Air Toxic Emission Factor (XATEF) database[83] provides a list of possible sources for a number of toxic air pollutants. The Standard Industrial Classification (SIC) Codes identified in the report as possible butadiene sources are shown in Table 7-6.

Data collected by NIOSH during the 1972-1974 National Occupational Health (NOH) survey[84,85] identify additional potential emission sources, which are also listed in Table 7-6. This work was designed specifically to estimate the number of workers (grouped by SIC Code) potentially exposed to butadiene. In some cases, the "potential exposure" determination was supported by observing butadiene in use. However, many of these cases were based on trade name product use; that is, the product used was derived from butadiene or may otherwise have a potential to contain butadiene.[84] In a 1981-1983 NOH survey, six additional industries were identified as posing a potential for worker exposure. These industries are also included in Table 7-6.

It is important to remember that these data were collected by NIOSH to assess worker exposure. They do not necessarily translate directly into atmospheric emission sources because of possible in-plant controls and butadiene removal as a result of its reactivity. However, the list represents several possible sources that may not otherwise be immediately identified as having a butadiene emissions potential.

Another reference for butadiene sources was the 1992 Toxic Chemical Release Inventory Data Base,[74] in which industry reporting of butadiene releases for 1993 were identified by SIC Code and are included in Table 7-6.

TABLE 7-6. POTENTIAL SOURCE CATEGORIES OF BUTADIENE EMISSIONS

1990 SIC Code	1990 Description
2269[a]	Dyeing and finishing of textiles (except wool fabrics and unit-finishers of textiles) not elsewhere classified
2273[b] (2272[c])	Carpets and rugs
2621[d]	Paper and allied products - paper mills
2631[c]	Paperboard mills
2652[b]	Paperboard containers and boxes - set up paperboard boxes
2812[d]	Industrial inorganic chemicals - alkalis and chlorine
2819[d]	Industrial inorganic chemicals not elsewhere classified
2821[d]	Plastics materials and resins
2822[d]	Synthetic rubber
2851[b]	Paints and allied products
2865[d]	Cyclic crudes and intermediates
2869[d]	Industrial organic chemicals not elsewhere classified
2879[d]	Pesticides and agricultural chemicals not elsewhere classified
2899[d]	Chemicals and chemical preparations not elsewhere classified
2911[d]	Petroleum refining
2951[b]	Asphalt paving and roofing materials - paving mixtures and blocks
2992[d]	Miscellaneous products of petroleum and coal - lubricating oils and greases
3011[b]	Rubber and miscellaneous plastics products - tires and inner tubes
3021[a]	Rubber and plastics footwear
3052[b,e] (3041)	Rubber and plastics hose and belting
3069[b,e] (3031)	Fabricated rubber products not elsewhere classified
308[b], 3432[b] (3079)	Miscellaneous plastics products, plumbing fixtures fitting and trim
3357[b]	Nonferrous wire drawing and insulating
3494[b]	Miscellaneous fabricated metal products - valves and pipe fittings not elsewhere classified
3499[b,e]	Fabricated metal products not elsewhere classified
3533[b]	Construction, mining, and material handling machinery and equipment - oil and gas field machinery
3569[b]	General industry machinery and equipment not elsewhere classified
3585[b]	Air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment
3621[b]	Electrical industrial apparatus - motors and generators
3643[b]	Electric lighting and wiring equipment - current-carrying wiring devices
3651[b]	Household audio and video equipment

TABLE 7-6. CONTINUED

1990 SIC Code	1990 Description
3721[b]	Aircraft and parts - aircraft
3799[b]	Transportation equipment not elsewhere classified
3841[b]	Surgical and medical instruments
3996[b]	Linoleum, asphalted felt-base, and other hard surface floor coverings not elsewhere classified
4226[a]	Special warehousing and storage, not elsewhere classified
5014[c]	Motor vehicles and motor vehicle parts and supplies - tires and tubes
5162[b], 5169[b]	Chemicals and allied products - plastic materials and (5161[a]) basic forms and shapes not elsewhere classified
5171[b]	Petroleum and petroleum products - petroleum bulk stations and terminals
5541[b]	Gasoline service stations
6513[b]	Real estate operators - apartment buildings
7319[b]	Advertising not elsewhere classified
7538[c]	Automotive repair shops - general
806[b]	Hospitals
8372, 8741-8743[b], 8748[b] (7392)	Commercial economic, sociological, and educational research, management, and public relations services except facilities support
8731[d] (7391[c])	Research, development and testing services - commercial physical and biological research

[a] SIC Code is listed as a potential source in the EPA XATEF document, Reference 83.
[b] This source is from the NIOSH NOH 1972-1974 survey, Reference 85. This is the current SIC Code for this category; the code in parentheses was the code for the category at the time of the survey.
[c] SIC Code was identified as possible butadiene source during the NIOSH NOH 1981-1983 survey, Reference 85.
[d] SIC Code was identified from the Toxic Release Chemical Inventory Database for 1993 submittals by industry, Reference 74.
[e] SIC Code is listed by both EPA and NIOSH.

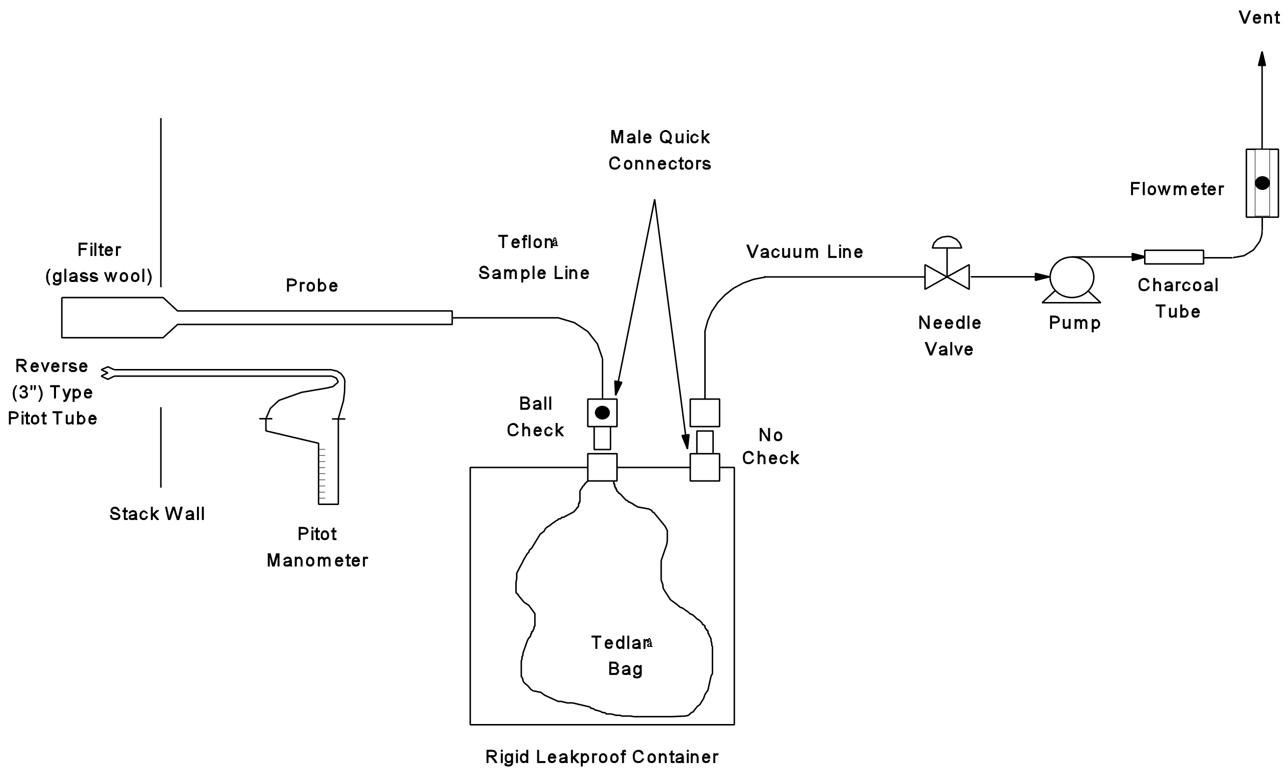
SECTION 8.0
SOURCE TEST PROCEDURES

1,3-Butadiene emissions can be measured by a number of methods. The following methods are applicable for measuring emissions from stationary sources, ambient air, and vehicle exhaust: (1) EPA Reference Method 18;[86] (2) NIOSH Analytical Method 1024;[87] (3) EPA Exhaust Gas Sampling System, Federal Test Procedure (FTP);[88] and (4) Auto/Oil Air Quality Improvement Research Program (AQIRP) speciation methodology.[89]

EPA Reference Method 18 applies to the sampling and analysis of approximately 90 percent of the total gaseous organics emitted from an industrial source, whereas NIOSH Method 1024 applies specifically to the collection and analysis of 1,3-butadiene from ambient air. The FTP and AQIRP methods measure vehicle exhaust by bag sampling and gas chromatography/flame ionization detector (GC/FID) analysis. All four methods are described in the following sections.

8.1 EPA REFERENCE METHOD 18

In Method 18, a sample of the exhaust gas to be analyzed is drawn into a Tedlar® or aluminized Mylar® bag as shown in Figure 8-1. The Tedlar® bag has been used for some time in the sampling and analysis of source emissions for pollutants. The cost of the Tedlar® bag is relatively low, and analysis by GC is easier than with a stainless steel cylinder sampler, because pressurization is not required to extract the air sample in the gas chromatographic analysis process.[90] The bag is placed inside a rigid, leakproof container and evacuated. The bag is then connected by a Teflon® sampling line to a sampling probe (stainless steel, Pyrex® glass,



Source: Reference 86

Figure 8-1. Integrated Bag Sampling Train or Teflon®) at the center of the stack. The sample is drawn into the bag by pumping air out of the rigid container.

The sample is then analyzed by GC coupled with FID. Based on field and laboratory validation studies, the recommended time limit for analysis is within 30 days of sample collection.[91] One recommended column is the 6-ft (1.82-m) Supelco Porapak QS.[92] However, the GC operator should select the column and GC conditions that provide good resolution and minimum analysis time for 1,3-butadiene. Zero helium or nitrogen should be used as the carrier gas at a flow rate that optimizes the resolution.

The peak areas corresponding to the retention times of 1,3-butadiene are measured and compared to peak areas for a set of standard gas mixtures to determine the 1,3-butadiene concentrations. The detection limit of this method ranges from about 1 ppm to an upper limit governed by the FID saturation or column overloading. However, the upper limit can be extended by diluting the stack gases with an inert gas or by using smaller gas sampling loops.

Recent work by EPA's Atmospheric Research and Exposure Assessment Laboratory has produced a modified version of Method 18 for stationary source sampling.[90,93] One difference is in the sampling rate, which is reduced to allow collection of more manageable gas volumes. By reducing the gas volumes, smaller Tedlar® bags (5 to 7L) can be used instead of the traditional 25-L or larger bags, which are not very practical in the field, especially when a large number of samples is required.[90] A second difference is the introduction of a filtering medium to remove entrained liquids, which improves the butadiene quantitation precision.

Two other changes involve the analytical procedure. The first uses picric acid in a second column (2 m x 1/8" stainless steel column, 0.19 percent picric acid on 80/100 mesh Carbopak C) to minimize the interference by butane and butene isomers that are also present in the stream. The second uses a backflush-to-vent configuration to remove any high-boiling compounds that have been collected before they reach the picric acid column. These modifications allow more accurate quantitation of butadiene to be performed in a shorter time period than with Method 18.

8.2 NIOSH METHOD 1024

NIOSH Method 1024 is appropriate for measuring ambient emissions of 1,3-butadiene in the workplace. In this NIOSH method, samples are collected with adsorbent tubes containing charcoal that has been washed and coated with 10 percent by weight 4-tert-butylcatechol (TBC-charcoal), a chemical known to inhibit the polymerization of 1,3-butadiene. Three-liter air samples should be collected with the use of a personal sampling pump at a flow rate of 0.05 L/min.[87,94]

Samples are desorbed with carbon disulfide and analyzed by GC equipped with an FID and a column capable of resolving 1,3-butadiene from the solvent front and other interferences. The column specified in NIOSH Method 1024 is a 50-m x 32-mm internal diameter, fused-silica, porous-layer, open-tubular column coated with aluminum oxide and potassium chloride (Al_2O_3/KCl).[87] Degradation of compound separation may be eliminated by using a back flushable precolumn [e.g., 10-m x 0.5-mm interior diameter fused-silica (CP Wax 57 CB)]. The precolumn allows light hydrocarbons to pass through, but water, methylene chloride, and polar or high-boiling components are retained and can be backflushed.[87,93]

The amount of 1,3-butadiene in a sample is obtained from the calibration curve in units of micrograms per sample. Collected samples are sufficiently stable to permit 6 days of ambient sample storage before analysis. If samples are refrigerated, they are stable for 18 days. Butadiene can dimerize during handling and storage. The rate of dimerization is a function of temperature, increasing with increasing temperature. Consequently, samples should be stored at low temperatures.

This procedure is applicable for monitoring 1,3-butadiene air concentrations ranging from 0.16 ppm to 36 ppm, and is more sensitive and selective than the previously-used

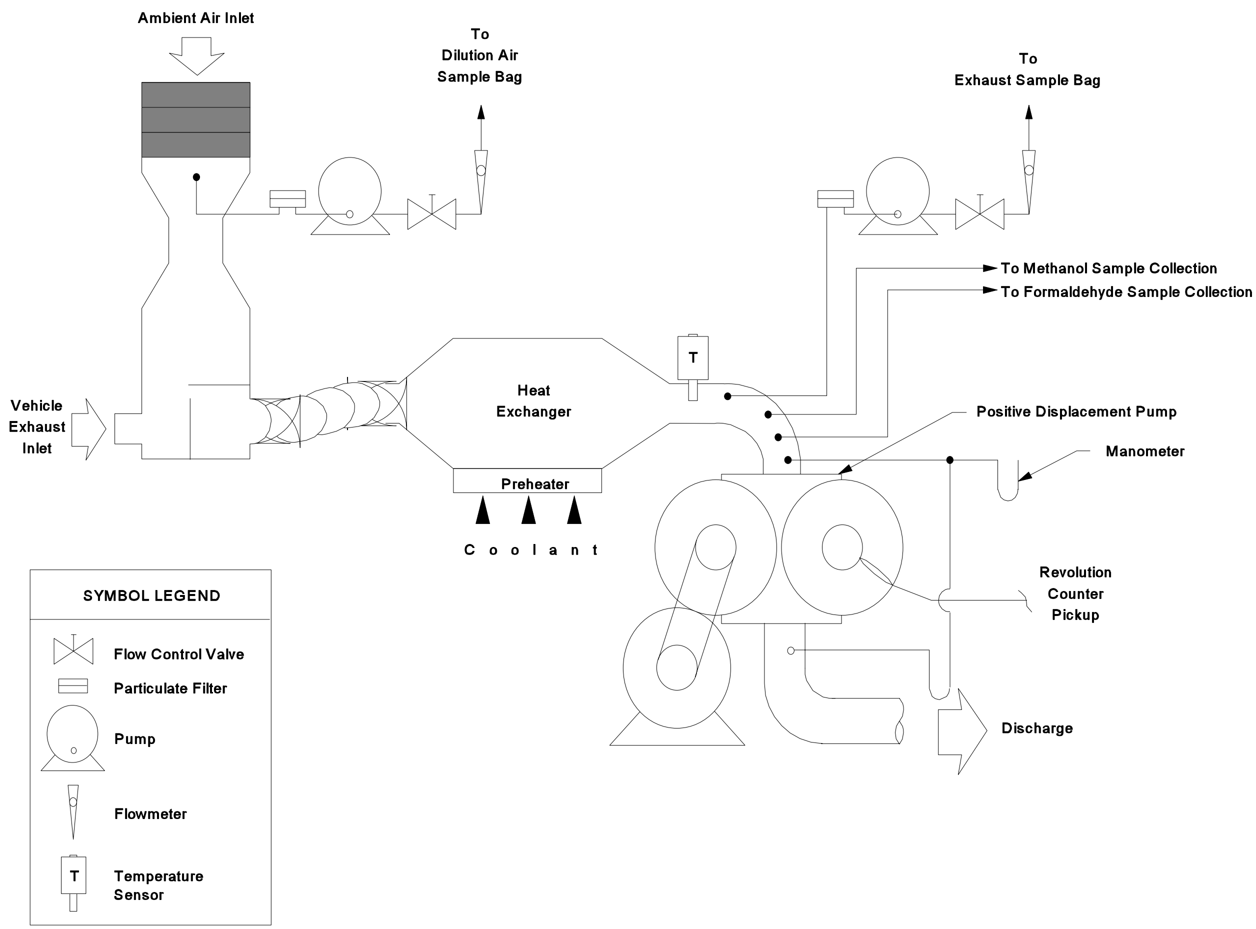
NIOSH Method S-91.[95] The GC column and operating conditions should provide good resolution and minimum analysis time.

8.3 FEDERAL TEST PROCEDURE

The most widely-used test procedure for sampling emissions from vehicle exhaust is the FTP, which was initially developed in 1974.[88,96,97] The FTP uses the Urban Dynamometer Driving Schedule (UDDS), which is 1,372 seconds in duration. An automobile is placed on a chassis dynamometer where it is run according to the following schedule: 505 seconds of a cold-start; 867 seconds of hot transient; and 505 seconds of a hot-start. (The definitions of the above terms can be found in the FTP description in the 40 CFR, Section 86).[88] The vehicle exhaust is collected in Tedlar® bags during the three testing stages. It should be noted that, in most cases, the majority of 1,3-butadiene is generated in bag one, the first 505-second segment of the cold-start UDDS cycle.[98]

The most widely used method for transporting the vehicle exhaust from the vehicle to the bags is a dilution tube sampling arrangement identical to the system used for measuring criteria pollutants from mobile sources.[88,98] Dilution techniques are used for sampling auto exhaust because in theory, dilution helps simulate the conditions under which exhaust gases condense and react in the atmosphere. Figure 8-2 shows a diagram of a vehicle exhaust sampling system.[99] Vehicle exhausts are introduced at an orifice where the gases are cooled and mixed with a supply of filtered dilution air. The diluted exhaust stream flows at a measured velocity through the dilution tube and is sampled isokinetically.

The major advantage in using a dilution tube approach is that exhaust gases are allowed to react and condense onto particle surfaces prior to sample collection, providing a truer composition of exhaust emissions as they occur in the atmosphere. Another advantage is that the dilution tube configuration allows simultaneous monitoring of hydrocarbons, carbon monoxide, carbon dioxide, and nitrogen oxides. Back-up sampling techniques, such as filtration/adsorption, are generally recommended for collection of both particulate- and gas-phase emissions.[97]



Source: Reference 99

Figure 8-2. Vehicle Exhaust Gas Sampling System

0045_ERG.PRE

8.4 AUTO/OIL AIR QUALITY IMPROVEMENT RESEARCH PROGRAM SPECIATION METHOD

Although there is no EPA-recommended analytical method for measuring 1,3-butadiene from vehicle exhaust, the AQIRP method for the speciation of hydrocarbons and oxygenates is widely used.[89,97] This analytical method calls for a dual column GC with FID. A pre-column, 15-m x 0.53-mm interior diameter, 1 µm film, such as the DB-WAX (J & W Scientific Co, Folsom, CA), is recommended to retain water and alcohols while allowing the lower molecular weight hydrocarbons to pass rapidly through to the analytical column.[89] A backflush valve can be activated to prevent the polar species and higher hydrocarbons from entering the analytical column, and to backflush these species from the pre-column. The recommended analytical column is a 50-m x 0.53-mm interior diameter, 10 µm film, porous layer open tubular (PLOT) column of alumina deactivated by potassium chloride.[89]

The peak areas corresponding to the retention times of 1,3-butadiene are measured and compared to peak areas for a set of standard gas mixtures to determine the 1,3-butadiene concentrations. The detection limit for this method is on the order of 0.03 ppmC in dilute exhaust for 1,3-butadiene (0.5 mg/mile for the FTP).[98]

It should be noted that sample instability has been shown to be a problem for 1,3-butadiene in exhaust mixtures. Therefore, to minimize concerns about sample integrity, exhaust emissions should be analyzed promptly (within 1 hour of collection).[98,100]

SECTION 9.0

REFERENCES

1. U.S. EPA. *Protocol for Equipment Leak Emission Estimates*. EPA-453/R-95-017. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, 1995.

2. *Federal Register*, 52 FR 21152, June 4, 1987.

3. U.S. EPA. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*. EPA-454/B-93-050. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, October 1993.

4. Factor Information Retrieval System Version 2.62 (FIRE 2.62). Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, March 1994.

5. Kirshenbaum, I. Butadiene. In: *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd ed, Volume 4. New York, New York: John Wiley and Sons, 1978.

6. Hawley, G.G. 1,3-Butadiene. In: *The Condensed Chemical Dictionary*, 10th ed., New York, New York: Van Nostrand Reinhold Company, Inc., 1981. p. 177.

7. Sittig, M. 1,3-Butadiene. In: *Handbook of Toxic and Hazardous Chemicals and Carcinogens*, 2nd ed., Park Ridge, New Jersey: Noyes Publications, 1985. pp. 153 to 154.

8. Chemical Profile: Butadiene. *Chemical Marketing Reporter*. 245(15):53, April 1994.

9. U.S. EPA. *Atmospheric Persistence of Eight Air Toxics*. EPA-600/3-87-004. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Atmospheric Sciences and Research Lab, January 1987. pp. 42 to 44.

10. Butadiene. In: *Chemical Products Synopsis*. Asbury Park, New Jersey: Mannsville Chemical Products Corp, September 1993.

11. Chemical Profile: SB Rubber. *Chemical Marketing Reporter*. 245(22):45, May 1994.

12. Chemical Profile: Polybutadiene. *Chemical Marketing Reporter*. 245(19):45, May 1994.

13. Chemical Profile: Neoprene. *Chemical Marketing Reporter*. 233(19):37, May 1988.

14. Chemical Profile: ABS Resins. *Chemical Marketing Reporter*. 239(16):41, April 1991.

15. Chemical Profile: Nitrile Rubber. *Chemical Marketing Reporter*. 239(20):33,50, May 1991.

16. Buchanan, S.K. (Radian Corporation) and B. Theismann (International Institute of Synthetic Rubber Producers). Telephone conversation. September 19, 1994.

17. U.S. EPA. *Motor Vehicle-Related Air Toxics Study*. Section 7.0: 1,3-Butadiene. EPA-420/R-93-005. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, 1993. pp. 7-1 to 7-7.

18. U.S. Department of Transportation. *Highway Statistics*. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1993. p. 208.

19. Kuhn, K.Q. and R.A. Wassel (Radian Corporation). Memorandum to the Butadiene Source Category Concurrence File concerning "Estimates of 1,3-Butadiene Emissions from Production Facilities and Emissions Reductions Achievable with Additional Controls," March 25, 1986.

20. Haddeland, G.E. Butadiene. Process Economics Program, Report No. 35. Menlo Park, California: Stanford Research Institute, 1968. Cited in reference 19, p. 9.

21. Standifer, R.L. Report 7: Butadiene. In: *Organic Chemical Manufacturing: Selected Processes*, Volume 10. EPA-450/3-80-028. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, 1980. Cited in reference 19, p. 15.

22. U.S. EPA. *Evaluation of PCB Destruction Efficiency in an Industrial Boiler*. EPA-600/2-81-055a. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, 1981. Cited in reference 19, p. 18.

23. U.S. EPA. *Efficiency of Industrial Flares: Test Results*. EPA-600/2-84-095. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Research and Development, Industrial Research Laboratory, May, 1984. p. 5-7.

24. U.S. EPA. *Control Technologies for Hazardous Air Pollutants*. EPA/625/6-91/014. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, 1991. pp. 3-1 to 3-3, 3-23.

25. Randall, J. L., et al. (Radian Corporation, Research Triangle Park, North Carolina). "Fugitive Emissions from the 1,3-Butadiene Production Industry: A Field Study, Final Report." Prepared for the 1,3-Butadiene Panel of the Chemical Manufacturers Association, 1989. pp. 5-30, 35, 41, 47, 53, 58, 63, 68.

26. U.S. EPA. *Protocol for Generating Unit-Specific Emission Estimates for Equipment Leaks of VOC and VHAP*. EPA-450/3-88-010. Research Triangle Park, North Carolina:

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, October 1988.

27. Wassel R.A. and K.Q. Kuhn (Radian Corporation). Memorandum to the Butadiene Source Category Concurrence File concerning "Estimates of 1,3-Butadiene Emissions from Styrene-Butadiene Copolymer Facilities and Emissions Reductions Achievable with Additional Controls," April 8, 1986.

28. *Shreve's Chemical Process Industries*. New York, New York: McGraw-Hill, 1984. p. 701.

29. SRI International. *1993 Directory of Chemical Producers - USA*. Menlo Park, California: SRI International, 1993.

30. Chemical Profile: Polybutadiene. *Chemical Marketing Reporter*. 239(15):42, April 1991.

31. Epner, E.P. (Radian Corporation). Memorandum to the Butadiene Source Category Concurrence File concerning "Estimate of 1,3-Butadiene from Polybutadiene Facilities and Emissions Reductions Achievable with Additional Controls," March 27, 1986.

32. Epner, E.P. (Radian Corporation). Memorandum to the Butadiene Source Category Concurrence File concerning "Estimates for Short-Term Emissions of 1,3-Butadiene from Polybutadiene Production Facilities," May 5, 1986.

33. Mark, H.F., et al., eds. *Kirk-Othmer Concise Encyclopedia of Chemical Technology*. New York, New York: John Wiley and Sons, Inc., 1985. p. 789.

34. Stallings, J.M. (E.I. DuPont). Written communication to J.R. Farmer (U.S. Environmental Protection Agency), July 27, 1984.

35. Kuhn, K.Q. and R.C. Burt (Radian Corporation). Memorandum to the Butadiene Source Category Concurrence File concerning "Estimates of 1,3-Butadiene Emissions from Miscellaneous Sources and Emissions Reductions Achievable with Candidate NESHAP Controls," December 12, 1986.

36. Johnson, P.R. Neoprene. In: *Encyclopedia of Chemical Technology*, 3rd ed. Volume 8. R.E. Kirk, et al., eds. New York, New York: John Wiley and Sons, 1979. p. 521.

37. Epner, E.P. (Radian Corporation). Memorandum to the Butadiene Source Category Concurrence File concerning "Estimates of Short-Term Emissions of 1,3-Butadiene from Neoprene/Chloroprene Production Facilities," April 7, 1986.

38. Johnson, P.R. Chloroprene. In: *Encyclopedia of Chemical Technology*, 3rd ed. Volume 5. R.E. Kirk, et al., eds. New York, New York: John Wiley and Sons, 1979. pp. 773-785.

39. Epner, E.P. (Radian Corporation). Memorandum to L.B. Evans (U.S. Environmental Protection Agency, Chemicals and Petroleum Branch) concerning "Estimates of 1,3-Butadiene Emissions from Neoprene Facilities and Emissions Reductions Achievable

with Additional Controls," December 23, 1985.

40. Burt, R. and R. Howle (Radian Corporation). Memorandum to L.B. Evans (U.S. Environmental Protection Agency, Chemicals and Petroleum Branch) concerning "Estimates of Acrylonitrile, Butadiene, and other VOC Emissions and Controls for ABS and NBR Facilities," January 29, 1986.

41. Energy and Environmental Analysis, Inc. *Source Category Survey for the Acrylonitrile Industry - Draft Report. ABS/SAN Operations: Emissions and Control Data*. Prepared for U.S. Environmental Protection Agency, 1981. Cited in reference 40.

42. Robinson, H.W. Nitrile Rubber. In: *Encyclopedia of Chemical Technology*, 3rd ed. Volume 8. R.E. Kirk, et al., eds. New York, New York: John Wiley and Sons, 1979. p. 534.

43. Niles, R.C. (Uniroyal Chemical Company). Written communication to J.R. Farmer (U.S. Environmental Protection Agency). September 4, 1984.

44. Cook, R. (U.S. Environmental Protection Agency, Ann Arbor, Michigan). Written communication to J. Mangino (Radian Corporation, Research Triangle Park, North Carolina). July 22, 1992.

45. Auto/Oil Air Quality Improvement Research Program. *Technical Bulletin No. 7: Emissions and Air Quality Modeling Results from Methanol/Gasoline Blends in Prototype Flexible/Variable Fuel Vehicles*. 1992.

46. U.S. EPA. *Analysis of Economic and Environmental Effects of Methanol as an Automotive Fuel*. Special Report. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, September 1989.

47. U.S. EPA. *Analysis of Economic and Environmental Effects of Ethanol as an Automotive Fuel*. Special Report. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, April 1990.

48. California Air Resources Board. *Definition of a Low-Emission Motor Vehicle in Compliance with the Mandates of Health and Safety Code Section 39037.05*. Assembly Bill 234, Leonard, 1987. El Monte, California: California Air Resources Board, Mobile Source Division, 1989.

49. California Air Resources Board. *Proposed Reactivity Adjustment Factors for Transitional Low-Emission Vehicles*: Technical Support Document, Updated Version. El Monte, California: California Air Resources Board, Mobile Source Division, November 13, 1991.

50. U.S. EPA. *Non-Road Engine and Vehicle Emission Study*. 21A-2001. Washington, D.C.: U.S. Environmental Protection Agency, Office of Air and Radiation, 1991. pp. 13, 14, 27, 28, 31, 32, 35, 36, 39, 40, I38.

51. Ingalls, M.N. *Non-road Emission Factors of Air Toxics*. Interim Report No. 2. SWRI 08-3426-005. Ann Arbor, Michigan: U.S. Environmental Protection Agency, June 1991. p. 23.

52. Booz-Allen and Hamilton. *Commercial Marine Vessel Contribution to Emission Inventories*. Final Report. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Motor Vehicle Emission Laboratory, October 7, 1991. Sections 1.0 and 2.0.

53. U.S. EPA. *Mobile Sources Procedures for Emission Inventory Preparation*, Volume IV: Mobile Sources. Section 6.0 - Emissions for Locomotives. EPA-450/4-81-026d (Revised). Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, 1992.

54. U.S. EPA. *Motor Vehicle-Related Air Toxic Study*. EPA-420/R-93-005. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, April 1993.

55. U.S. Department of Transportation. *Census of U.S. Civil Aircraft.* Washington, D.C.: U.S. Department of Transportation, Federal Aviation Administration, Office of Management Systems, 1989.

56. U.S. EPA. *Toxic Emissions from Aircraft Engines*. EPA-453/R-93-028. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, July 1993. pp. 1-6.

57. U.S. Department of Transportation. *Federal Aviation Engine Emission Database*. Washington, D.C.: U.S. Department of Transportation, Office of Environment and Energy, Federal Aviation Administration, 1991.

58. U.S. EPA. *Volatile Organic Compound/Particulate Matter Speciation Data System (SPECIATE)*. Version 1.5. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, October 1992.

59. Vigyan Inc. *Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southwest Chicago*. U.S. Environmental Protection Agency, Air and Radiation Division, April 1993.

60. U.S. EPA. *Mobile Sources Procedures for Emission Inventory Preparation*, Volume IV: Mobile Sources. Section 5.0 - Emissions from Aircraft. EPA-450/4-81-026d (Revised). Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, 1992.

61. U.S. Department of Transportation. *Federal Aviation Administration Air Traffic Activity, Fiscal Year 1993*. Washington, D.C.: Federal Aviation Administration, Office of Aviation Policy Plans and Management Analysis, 1994.

62. California Air Resources Board. *Air Sampling for Chemical Analysis from Rocket Engine Test Firing Plumes*. Final Report. Confidential Report No. ERC-57. June 1992.

63. U.S. Department of Health and Human Services. *Industrial Hygiene Walk-through Survey Report of Denka Chemical Corporation, Houston, Texas*. (July 30, 1985, Survey). DHHS (NIOSH) Publication No. 1W/147.27 (PB86-225406). Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1986.

64. U.S. Department of Health and Human Services. *Industrial Hygiene Walk-through Survey Report of Calhio Chemicals, Inc., Perry, Ohio, subsidiary of Stauffer Chemical Company, Perry, Ohio*. (August 14, 1985, Survey). DHHS (NIOSH) Publication No. 1W/147.24 (PB86-224458). Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1986.

65. S.K. Buchanan (Radian Corporation) with E. Urig, (July 25, 1988) and T. Lewis, (July 26, 1988), B. F. Goodrich. Telephone communications.

66. Benjamin, B.K. and R.W. Novak. Graft Copolymerization. In: *Encyclopedia of Chemical Technology*, 3rd ed. Volume 15. New York, New York: John Wiley and Sons, 1978. pp. 389-390.

67. U.S. Department of Health and Human Services. *Industrial Hygiene Walk-through Survey Report of E. I. DuPont de Nemours Company, Beaumont Works Facility, Beaumont, Texas.* (August 28, 1985, Survey). DHHS (NIOSH) Publication No. 1W/147.33 (PB86-225380). Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1986.

68. Kirschenbaum, I. Diels-Alder Reactions. In: *Encyclopedia of Chemical Technology*, 3rd ed. Volume 4. R.E. Kirk, et al., eds. New York, New York: John Wiley and Sons, 1978. pp. 315-316.

69. U.S. Department of Health and Human Services. *Industrial Hygiene Survey Report of Phillips Chemical Company, Philtex Plant, Borger, Texas*. (August 7, 1985, Survey). DHHS (NIOSH) Publication No. 1W/147.23 (PB86-222395). Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1986.

70. Bisio, A.L. and B.R. Tegge. Ethanol - Propylene Elastomers In: *Encyclopedia of Chemical Processing and Design*. Volume 20. J.J. McKetta and W.A. Cunningham, eds. New York, New York: Marcel Dekker, Inc., 1984. pp. 343-345.

71. Khan, Z.S., and T.W. Hughes (Monsanto Research Corporation). *Source Assessment: Polyvinyl Chloride*. EPA-600/2-78-004i. Cincinnati, Ohio: U.S. Environmental Protection Agency, 1978. p. 14.

72. White, T.S. (Radian Corporation). *Volatile Organic Compound Emissions from Rubber Processing Facilities at Downstream POTW,* Final Report. EPA Contract No. 68-02-4398. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, 1987.

73. U.S. EPA. *Final Background Information Document for Secondary Lead NESHAP*. EPA-450/R-94-024a. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, June 1994.

74. U.S. EPA. *1992 Toxic Chemical Release Inventory (SARA 313) Database*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Toxic Substances, 1993.

75. Zarate, M. (Radian Corporation). Memorandum to James Durham (U.S. Environmental Protection Agency) concerning "Process Vent Information Collection Request Data Quality Analysis," August 25, 1993.

76. Ward, D.E., and W.M. Hao. Air Toxic Emissions from Burning of Biomass Globally - Preliminary Estimates. Presented at the 85th Annual Meeting and Exhibition of the Air and Waste Management Association, June 1992. pp. 2-13.

77. Campbell, D.L. and J. Mangino (Radian Corporation). Evaluation and Improvement of the Puget Sound Toxic Air Contaminants Emissions Inventory. Technical Note. EPA Contract No. 68-D1-0031. Washington D.C.: U.S. Environmental Protection Agency, Office of Research and Development, May 1994.

78. Peterson, J. and D. Ward. *An Inventory of Particulate Matter and Air Toxic Emissions from Prescribed Fires in the United States for 1989*. U.S. Department of Agriculture, Forest Service, 1989. pp. 1-16.

79. U.S. EPA. *Compilation of Air Pollutant Emission Factors*, 5th ed. (AP-42), Vol I: Stationary Point and Area Sources. Section 2.4. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, October 1992.

80. AP-42, 5th ed., *op. cit.*, note 79. Section 11.1, 1995.

81. Lemieux, P.M., and D.M. DeMarini. *Mutagenicity of Emissions from the Simulated Open Burning of Scrap Rubber Tires*. EPA-600/R-92-127. Washington, D.C.: U.S. Environmental Protection Agency, July 1992.

82. AP-42, 5th ed., *op. cit.*, note 79. Section 3.3, 1995.

83. U.S. EPA. *Crosswalk/Air Toxic Emission Factor (XATEF) Database*. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, 1987.

84. Buchanan, S.K. (Radian Corporation) and J. Seta (NIOSH Hazard Section, Cincinnati, Ohio). Telephone communication, July 26, 1988.

85. "National Occupational Hazard Surveys, extracted data from 1972-1974 and 1981-1983," printouts received by S.K. Buchanan, Radian Corporation, from J. Seta, NIOSH Hazard Section, Cincinnati, Ohio. July 1987.

86. *Federal Register*. 48 FR 48344-46361, October 18, 1983.

87. U.S. Department of Health, Education, and Welfare. *NIOSH Manual of Analytical Methods*, 3rd ed. Volume 1. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1984. pp. 1024-1 to 1024-9.

88. U.S. Code of Federal Regulations, Title 40, Protection of the Environment, Part 86, Subpart B, Emission Regulations for 1977 and Later Model Year New Light-Duty Vehicles and New Light-Duty Trucks; Test Procedures. Washington, D.C.: U.S. Government Printing Office, 1993.

89. Siegl, W.D., et al. Improved Emissions Speciation Methodology for Phase II of the Auto/Oil Air Quality Improvement Research Program - Hydrocarbons and Oxygenates. Presented at the International Congress and Exposition, Detroit, Michigan. SAE Technical Paper Series. Warrendale, Pennsylvania: SAE, March 1993. pp. 63-98.

90. Pau, J.C., J.E. Knoll and M.R. Midgett. A Tedlar® Bag Sampling System for Toxic Organic Compounds in Source Emission Sampling and Analysis. *Journal of Air and Waste Management Association*. 41(8):1095-1097, August 1991.

91. Moody, T.K. (Radian Corporation) and J. Pau (U.S. Environmental Protection Agency, Emissions Monitoring Systems Laboratory). Written communication, June 6, 1988.

92. Acurex Corporation. *Acurex Interim Report: Development of Methods for Sampling 1,3-Butadiene*. 1987. pp. 4-1 through 4-18.

93. Entropy Environmentalists, Inc. *Sampling and Analysis of Butadiene at a Synthetic Rubber Plant*. EPA Contract No. 68-02-4442. U.S. Environmental Protection Agency, Atmospheric Research and Exposure Assessment Laboratory, Quality Assurance Division, 1988. pp. 3-5.

94. Hendricks, W.D., and G.R. Schultz. A Sampling and Analytical Method for Monitoring Low ppm Air Concentrations of 1,3-Butadiene. *Appl. Ind. Hyg.*, 1(4):186-190, 1986.

95. Fajen, J.M., D.R. Roberts, L.J. Ungers, and E.R. Krishnan. Occupational Exposure of Workers to 1,3-Butadiene. *Environmental Health Perspectives*. 86:11-18, 1990.

96. Blackley, C. (Radian Corporation) and R. Zweidinger (U.S. Environmental Protection Agency). Telephone communication, May 10, 1994.

97. Blackley, C. (Radian Corporation) and P. Gabele (U.S. Environmental Protection Agency). Telephone communication, May 10, 1994.

98. U.S. EPA. *Butadiene Measurement Technology*. EPA 460/3-88-005. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Source Air Pollution Control, 1988. pp. 1-23, A1-15, B1-5, C1-3.

99. Lee, F.S., and D. Schuetzle. Sampling, Extraction, and Analysis of Polycyclic Aromatic Hydrocarbons from Internal Combustion Engines. In: *Handbook of Polycyclic Aromatic Hydrocarbons*, A. Bjorseth, ed. New York, New York: Marcel Dekker, Inc., 1985. p. 30.

100. Hoekman, S.K. Improved Gas Chromatography Procedure for Speciated Hydrocarbon Measurements of Vehicle Emissions. *Journal of Chromatography*, 639:239-253, 1993.

APPENDIX A

EMISSION FACTOR SUMMARY TABLE

TABLE A-1. SUMMARY OF EMISSION FACTORS BY SOURCE CLASSIFICATION CODE

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
2-02-001-01 Internal Combustion Engines - Industrial	Distillate Oil/Diesel, Reciprocating	Uncontrolled	---	<.0000391 lb/MMBtu (<0.017 ng/J)	E
2-03-001-01 Internal Combustion Engines - Commercial/ Industrial	Distillate Oil/Diesel, Reciprocating	Uncontrolled	---	<.0000391 lb/MMBtu (<0.017 ng/J)	E
3-01 Butadiene Dimers	Process Vents	Controlled	---	0.030 lb/ton[c] (0.015 kg/Mg)	U5
		Uncontrolled	---	1.54 lb/ton[c] (0.77 kg/Mg)	U5
	Equipment Leaks	Controlled	---	4.3 tons/yr[c] (3.9 Mg/yr)	U5
3-01 Butadiene-furfural Cotrimers	Process Vents	Controlled	---	440 lb/ton[c] (220 kg/Mg)	U5
		Uncontrolled	---	440 lb/ton[c] (220 kg/Mg)	U5
	Equipment Leaks	Controlled	---	1.1 tons/yr[c] (0.5 Mg/yr)	U5
3-01 1,4-Hexadiene	Equipment Leaks	Controlled	---	59.3 tons/yr[c] (53.8 Mg/yr)	U5
		Uncontrolled	---	67.7 tons/yr[c] (61.4 Mg/yr)	U5

TABLE A-1. CONTINUED

	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
3-01 Sulfolane	Equipment Leaks	Controlled	1.8 - 14.7 tons/yr[c] (1.6 - 13.3 Mg/yr)	---	U5
		Uncontrolled	1.8 - 14.7 tons/yr[c] (1.6 - 13.3 Mg/yr)	---	U5
3-01 Tetrahydrophthalic Anhydride/Acid	Equipment Leaks	Controlled	---	2.4 tons/yr[c] (2.2 Mg/yr)	U5
		Uncontrolled	---	2.4 tons/yr[c] (2.2 Mg/yr)	U5
3-01-026 SB Copolymer Production	Process vents	Controlled	0.00024 - 94.34 lb/ton[d] (0.00012 - 47.17 kg/Mg)	7.10 lb/ton[d] (3.55 kg/Mg)	D
		Uncontrolled	0.124 - 94.34 lb/ton[d] (0.062 - 47.17 kg/Mg)	14.20 lb/ton[d] (7.10 kg/Mg)	D
3-01-026 SB Copolymer Production	Equipment leaks	Uncontrolled	0.11 - 23.59 tons/yr[d] (0.10 - 21.40 Mg/yr)	7.28 tons/yr[d] (6.60 Mg/yr)	D
3-01-026 SB Copolymer Production	Wastewater	Controlled	0 - <10 lb/ton[d] (0 - <5 kg/Mg)[e]	0.30 lb/ton[d] (0.15 kg/Mg)	D
3-01-026 SB Copolymer Production	Other liquid waste	Controlled	<0.02 lb/ton[d] (<0.01 kg/Mg)	<0.02 lb/ton[d] (<0.01 kg/Mg)	D
3-01-026 SB Copolymer Production	Solid waste	Controlled	0 - <0.02 lb/ton[d] (0 - <0.01 kg/Mg)[e]	<0.02 lb/ton[d] (<0.01 kg/Mg)	D

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
3-01-026 Polybutadiene Production	Process vents	Controlled	0.00008 - 36.06 lb/ton[f] (0.00004 - 18.03 kg/Mg)	6.14 lb/ton[f] (3.07 kg/Mg)	U5
		Uncontrolled	0.0032 - 36.06 lb/ton[f] (0.0016 - 18.03 kg/Mg)	8.96 lb/ton[f] (4.48 kg/Mg)	U5
3-01-026 Polybutadiene Production	Equipment leaks	Controlled	4.04 - 31.42 tons/yr[f] (3.66 - 28.50 Mg/yr)	10.41 tons/yr[f] (9.44 Mg/yr)	U5
		Uncontrolled	4.04 - 31.42 tons/yr[f] (3.66 - 28.50 Mg/yr)	10.41 tons/yr[f] (9.44 Mg/yr)	U5
3-01-026 Polybutadiene Production	Wastewater	Controlled	0 - 0.74 lb/ton[f] (0 - 0.38 kg/Mg)	0.24 lb/ton[f] (0.12 kg/Mg)	U5
		Uncontrolled	0 - 0.74 lb/ton[f] (0 - 0.38 kg/Mg)	0.24 lb/ton[f] (0.12 kg/Mg)	U5
3-01-026 Polybutadiene Production	Solid waste	Controlled	0 lb/ton[f] (0 kg/Mg)	0 lb/ton[f] (0 kg/Mg)	U5
		Uncontrolled	0 lb/ton[f] (0 kg/Mg)	0 lb/ton[f] (0 kg/Mg)	U5
3-01-026 Neoprene Production	Process vents	Controlled	0.32 - 6.78 lb/ton[c] (0.16 - 3.89 kg/Mg)	4.04 lb/ton[c] (2.02 kg/Mg)	E
		Uncontrolled	0.40 - 24.18 lb/ton[c] (0.20 - 12.09 kg/Mg)	12.28 lb/ton[c] (6.14 kg/Mg)	E
3-01-026 Neoprene Production	Equipment leaks	Controlled	1.03 - 4.88 tons/yr[c] (0.93 - 4.43 Mg/yr)	2.95 tons/yr[c] (2.68 Mg/yr)	E
		Uncontrolled	1.03 - 4.88 tons/yr[c] (0.93 - 4.43 Mg/yr)	2.95 tons/yr[c] (2.68 Mg/yr)	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
3-01-026 Nitrile Elastomer Production	Process vents	Controlled	0.0004 - 17.80 lb/ton[c,g] (0.0001 - 8.90 kg/Mg)	~ 4 lb/ton[c,g,h] (~ 2 kg/Mg)	E
		Uncontrolled	0.030 - <50 lb/ton[c,g] (0.01 - <25 kg/Mg)	~ 16 lb/ton[c,g,h] (~ 8 kg/Mg)	E
3-01-026 Nitrile Elastomer Production	Equipment leaks	Uncontrolled	0.43 - 18.67 tons/yr[c,g] (0.39 - 16.93 Mg/yr)	8.74 tons/yr[c,g] (7.93 Mg/yr)	E
3-01-026 Nitrile Elastomer Production	Secondary sources	Controlled	0.002 - 0.018 lb/ton[c,g,i] (0.001 - 0.009 kg/Mg)	0.010 lb/ton[c,g,i] (0.005 kg/Mg)	E
		Uncontrolled	0.002 - 0.018 lb/ton[c,g,i] (0.001 - 0.009 kg/Mg)	0.010 lb/ton[c,g,i] (0.005 kg/Mg)	E
3-01-026 Butadiene-vinylpyridine Latex	Equipment Leaks	Controlled	---	0.61 tons/yr[c] (0.55 Mg/yr)	U5
3-01-153 Butadiene Cylinders	Process Vents	Controlled	---	43.2 lb/ton[c] (21.6 kg/Mg)	U5
		Uncontrolled	---	43.2 lb/ton[c] (21.6 kg/Mg)	U5
	Equipment Leaks	Controlled	---	<0.11 tons/yr[c] (<0.1 Mg/yr)	U5
		Uncontrolled	---	<0.11 tons/yr[c] (<0.1 Mg/yr)	U5
3-01-153 Butadiene Production - C_4 Stream Production	Process vents	Uncontrolled	0.0054 lb/ton[d] (0.0027 kg/Mg)	---	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
3-01-153 Butadiene Production - Recovery Process	Wastewater	Controlled	0.00068 - 4.4 lb/ton[d] (0.00034 - 2.2 kg/Mg)	0.936 lb/ton[d] (0.468 kg/Mg)	E
3-01-153 Butadiene Production - Recovery Process	Solid waste	Controlled	---	5.542×10^{-7} lb/ton[d] (4.988×10^{-7} kg/Mg)	E
3-01-153-01 Butadiene Production - Recovery Process	Process vents	Controlled	0.0068 - 0.0550 lb/ton[d] (0.0034 - 0.0275 kg/Mg)	0.0314 lb/ton[d] (0.0157 kg/Mg)	E
		Uncontrolled	0.0322 - 0.6872 lb/ton[d] (0.0161 - 0.3436 kg/Mg)	0.4652 lb/ton[d] (0.2326 kg/Mg)	E
3-01-153-80 Butadiene Production - Recovery Process	Equipment leaks[j]	Controlled	455 tons/yr[d] (407 Mg/yr)	---	E
3-01-254 Adiponitrile Production	Process vents	Controlled	0.12 lb/ton[d,g] (0.06 kg/Mg)	0.12 lb/ton[d,g] (0.06 kg/Mg)	U5
		Uncontrolled	5.84 - 6.30 lb/ton[d,g] (2.92 - 3.15 kg/Mg)	6.08 lb/ton[d,g] (3.04 kg/Mg)	U5
3-01-254 Adiponitrile Production	Secondary sources	Controlled	0.016 - 0.024 lb/ton[d,g] (0.008 - 0.012 kg/Mg)	0.02 lb/ton[d,g] (0.01 kg/Mg)	U5
		Uncontrolled	0.016 - 0.024 lb/ton[d,g] (0.008 - 0.012 kg/Mg)	0.02 lb/ton[d,g] (0.01 kg/Mg)	U5
3-01-254-20 Adiponitrile Production	Equipment leaks	Uncontrolled	2.72 - 5.25 tons/yr[d,g] (2.47 - 4.76 Mg/yr)	3.99 tons/yr[d,g] (3.62 Mg/yr)	U5

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
3-04-004-03 Secondary lead production	Blast furnace outlet	Uncontrolled	0.78 - 1.54 lb/ton (0.32 - 0.63 kg/Mg)	1.16 lb/ton (0.48 kg/Mg)	C
	Rotary furnace outlet	Uncontrolled	---	0.13 lb/ton (0.05 kg/Mg)	C
5-01-007-01 Wastewater treatment facility	Influent	Uncontrolled	---	1.7×10^3 lb/ton (771 g/kg)	U5
5-03-002-03 Open Burning of Tires	Chunk tires	Uncontrolled	---	234.28 lb/1,000 tons (117.14 mg/kg)	C
	Shredded tires	Uncontrolled	---	277.95 lb/1,000 tons (138.97 mg/kg)	C
6-41 Methylmethacrylate-butadiene-styrene Resins	Process Vents	Controlled	---	1.8 lb/ton[c] (0.9 kg/Mg)	U5
		Uncontrolled	---	17.2 lb/ton[c] (8.6 kg/Mg)	U5
	Equipment Leaks	Controlled	4.0 - 17.4 tons/yr[c] (3.6 - 15.8 Mg/yr)	---	U5
		Uncontrolled	---	17.4 tons/yr[c] (15.8 Mg/yr)	U5
6-41 ABS Production	Process vents	Controlled	0.16 - 10.66 lb/ton[c,k] (0.08 - 5.33 kg/Mg)	4.22 lb/ton[c,k] (2.11 kg/Mg)	E
		Uncontrolled	6.50 - 11.28 lb/ton[c,k] (3.25 - 5.64 kg/Mg)	9.48 lb/ton[c,k] (4.74 kg/Mg)	E
6-41 ABS Production	Equipment leaks	Controlled	1.21 - 3.50 tons/yr[c,k] (1.10 - 3.17 Mg/yr)	2.36 tons/yr[c,k] (2.14 Mg/yr)	E
		Uncontrolled	1.21 - 3.50 tons/yr[c,k] (1.10 - 3.17 Mg/yr)	2.36 tons/yr[c,k] (2.14 Mg/yr)	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
6-46-300-01 Polyvinyl chloride	Suspension process, entire plant	Uncontrolled	---	4.6 x 10^{-4} lb/ton (2.1 x 10^{-4} g/kg)	U5
6-84-350 Dodecanedioic Acid	Equipment Leaks	Controlled	---	5.73 tons/yr[c] (5.2 Mg/yr)	U5
		Uncontrolled	---	5.73 tons/yr[c] (5.2 Mg/yr)	U5
22-01-001-000 Light-Duty Gas Vehicle	Mobile	Uncontrolled	---	2 x 10^{-5} lb/mile (0.01 g/mile)	D
22-01-020-000 Light-Duty Gas Truck 1	Mobile	Uncontrolled	---	4 x 10^{-5} lb/mile (0.02 g/mile)	D
22-01-040-000 Light-Duty Gas Truck 2	Mobile	Uncontrolled	---	6 x 10^{-5} lb/mile (0.03 g/mile)	D
22-01-060-000 Light-Duty Gas Truck	Mobile	Uncontrolled	---	4 x 10^{-5} lb/mile (0.02 g/mile)	D
22-01-070-000 Heavy-Duty Gas Vehicle	Mobile	Uncontrolled	---	1 x 10^{-4} lb/mile (0.06 g/mile)	D
22-01-080-000 Motorcycle	Mobile	Uncontrolled	---	6 x 10^{-5} lb/mile (0.03 g/mile)	D
22-30-001-000 Light-Duty Diesel Vehicle	Mobile	Uncontrolled	---	2 x 10^{-5} lb/mile (0.01 g/mile)	D

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-30-060-000 Light-Duty Diesel Truck	Mobile	Uncontrolled	---	2 x 10^{-5} lb/mile (0.01 g/mile)	D
22-30-070-000 Heavy-Duty Diesel Vehicle	Mobile	Uncontrolled	---	1 x 10^{-4} lb/mile (0.05 g/mile)	D
22-60-001-010 Off-Road Motorcycles	2-stroke gas, exhaust	Uncontrolled	---	16.38 g/hr[l]	E
22-60-001-020 Snowmobiles	2-stroke gas, exhaust	Uncontrolled	---	2.978 g/hp-hr[l]	E
22-60-001-030 All Terrain Vehicles (ATV's)	2-stroke gas, exhaust	Uncontrolled	---	16.38 g/hr[l]	E
22-60-001-050 Golf Carts	2-stroke gas, exhaust	Uncontrolled	---	16.38 g/hr[l]	E
22-60-001-060 Specialty Vehicles Carts	2-stroke gas, exhaust	Uncontrolled	---	16.38 g/hr[l]	E
22-60-002-006 Tampers/Rammers	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-002-009 Plate Compactors	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-002-021 Paving Equipment	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-002-033 Bore/Drill Rigs	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-60-003-010 Aerial Lifts	2-stroke gas, exhaust	Uncontrolled	---	0.059 g/hp-hr[m,n]	E
	2-stroke gas, crank case	Uncontrolled	---	0.019 g/hp-hr[m,n]	E
22-60-003-020 Forklifts	2-stroke gas, exhaust	Uncontrolled	---	0.059 g/hp-hr[m,n]	E
	2-stroke gas, crank case	Uncontrolled	---	0.019 g/hp-hr[m,n]	E
22-60-003-030 Sweepers/Scrubbers	2-stroke gas, exhaust	Uncontrolled	---	0.056 g/hp-hr[m,n]	E
	2-stroke gas, crank case	Uncontrolled	---	0.019 g/hp-hr[m,n]	E
22-60-003-040 Other General Industrial Equipment	2-stroke gas, exhaust	Uncontrolled	---	4.056 g/hp-hr[n]	E
22-60-004-010 Lawn Mowers	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr	E
22-60-004-015 Tillers <5 hp	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-004-020 Chain Saws <4 hp	2-stroke gas, exhaust	Uncontrolled	---	8.135 g/hp-hr[l]	E
22-60-004-025 Trimmers/Edgers/ Brush Cutters	2-stroke gas, exhaust	Uncontrolled	---	6.131 g/hp-hr[l]	E
22-60-004-030 Leaf Blowers/ Vacuums	2-stroke gas, exhaust	Uncontrolled	---	5.878 g/hp-hr[l]	E
22-60-004-035 Snowblowers	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-004-050 Shredders <5 hp	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-004-070 Commercial Turf Equipment	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
22-60-004-075 Other Lawn and Garden Equipment	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-006-005 Generator Sets	2-stroke gas, exhaust	Uncontrolled	---	5.678 g/hp-hr[l]	E
22-60-006-010 Pumps	2-stroke gas, exhaust	Uncontrolled	---	0.117 g/hp-hr[l]	E
	2-stroke gas, crank case	Uncontrolled	---	0.018 g/hp-hr[l]	E
22-60-006-020 Gas Compressors	2-stroke gas, exhaust	Uncontrolled	---	0.084 g/hp-hr[m,n]	E
	2-stroke gas, crank case	Uncontrolled	---	0.018 g/hp-hr[m,n]	E
22-60-007-005 Chain Saws >4 hp	2-stroke gas, exhaust	Uncontrolled	---	4.15 g/hp-hr[l]	E
22-60-008-010 Terminal Tractors	2-stroke gas, exhaust	Uncontrolled	---	0.059 g/hp-hr[m,n]	E
	2-stroke gas, crank case	Uncontrolled	---	0.013 g/hp-hr[m,n]	E
22-65-001-010 Off-Road Motorcycles	4-stroke gas, exhaust	Uncontrolled	---	1.95 g/hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.429 g/hr[n]	E
22-65-001-030 All Terrain Vehicles (ATV's)	4-stroke gas, exhaust	Uncontrolled	---	2.73 g/hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.429 g/hr[l]	E
22-65-001-040 Minibikes	4-stroke gas, exhaust	Uncontrolled	---	2.73 g/hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.429 g/hr[l]	E
22-65-001-050 Golf Carts	4-stroke gas, exhaust	Uncontrolled	---	2.73 g/hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.429 g/hr[l]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-65-001-060 Specialty Vehicles Carts	4-stroke gas, exhaust	Uncontrolled	---	2.73 g/hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.429 g/hr[l]	E
22-65-002-003 Asphalt Pavers	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-006 Tampers/Rammers	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-009 Plate Compactors	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-015 Rollers	4-stroke gas, exhaust	Uncontrolled	---	0.253 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.04 g/hp-hr[l]	E
22-65-002-021 Paving Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-024 Surfacing Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-027 Signal Boards	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-030 Trenchers	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-033 Bore/Drill Rigs	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-036 Excavators	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-65-002-039 Concrete/Industrial Saws	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-042 Cement and Mortar Mixers	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-045 Cranes	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-054 Crushing/Proc. Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-057 Rough Terrain Forklifts	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-060 Rubber Tire Loaders	4-stroke gas, exhaust	Uncontrolled	---	0.108 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.024 g/hp-hr[n]	E
22-65-002-066 Tractors/Loaders/ Backhoes	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-072 Skid Steer Loaders	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E
22-65-002-078 Dumpers/Tenders	4-stroke gas, exhaust	Uncontrolled	---	0.177 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[l]	E
22-65-002-081 Other Construction Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.127 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.028 g/hp-hr[n]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-65-003-010 Aerial Lifts	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.029 g/hp-hr[n]	E
22-65-003-020 Forklifts	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.029 g/hp-hr[n]	E
22-65-003-030 Sweepers/Scrubbers	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.029 g/hp-hr[n]	E
22-65-003-040 Other General Industrial Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.027 g/hp-hr[n]	E
22-65-003-050 Other Material Handling Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.027 g/hp-hr[n]	E
22-65-004-010 Lawn Mowers	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E
22-65-004-015 Tillers <5 hp	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E
22-65-004-025 Trimmers/Edgers/ Brush Cutters	4-stroke gas, exhaust	Uncontrolled	---	0.66 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.104 g/hp-hr[l]	E
22-65-004-030 Leaf Blowers/ Vacuums	4-stroke gas, exhaust	Uncontrolled	---	0.53 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.083 g/hp-hr[l]	E
22-65-004-035 Snowblowers	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-65-004-040 Rear Engine Riding Mowers	4-stroke gas, exhaust	Uncontrolled	---	0.254 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.04 g/hp-hr[l]	E
22-65-004-045 Front Mowers	4-stroke gas, exhaust	Uncontrolled	---	0.254 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.04 g/hp-hr[l]	E
22-65-004-050 Shredders <5 hp	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E
22-65-004-055 Lawn and Garden Tractors	4-stroke gas, exhaust	Uncontrolled	---	0.257 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.04 g/hp-hr[l]	E
22-65-004-060 Wood Splitters	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E
22-65-004-065 Chippers/Stump Grinders	4-stroke gas, exhaust	Uncontrolled	---	0.735 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[n]	E
22-65-004-070 Commercial Turf Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.257 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.04 g/hp-hr[l]	E
22-65-004-075 Other Lawn and Garden Equipment	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E
22-65-005-010 2-Wheel Tractors	4-stroke gas, exhaust	Uncontrolled	---	0.15 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.024 g/hp-hr[l]	E
22-65-005-015 Agricultural Tractors	4-stroke gas, exhaust	Uncontrolled	---	0.107 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.024 g/hp-hr[n]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-65-005-020 Combines	4-stroke gas, exhaust	Uncontrolled	---	0.14 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.031 g/hp-hr[n]	E
22-65-005-030 Agricultural Mowers	4-stroke gas, exhaust	Uncontrolled	---	0.199 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.031 g/hp-hr[l]	E
22-65-005-035 Sprayers	4-stroke gas, exhaust	Uncontrolled	---	0.14 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.031 g/hp-hr[n]	E
22-65-005-040 Tillers >5 hp	4-stroke gas, exhaust	Uncontrolled	---	1.029 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.162 g/hp-hr[l]	E
22-65-005-045 Swathers	4-stroke gas, exhaust	Uncontrolled	---	0.14 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.031 g/hp-hr[n]	E
22-65-005-050 Hydro Power Units	4-stroke gas, exhaust	Uncontrolled	---	0.196 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.031 g/hp-hr[l]	E
22-65-005-055 Other Agricultural Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.14 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.031 g/hp-hr[n]	E
22-65-006-005 Generator Sets	4-stroke gas, exhaust	Uncontrolled	---	0.259 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.041 g/hp-hr[l]	E
22-65-006-010 Pumps	4-stroke gas, exhaust	Uncontrolled	---	0.259 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.041 g/hp-hr[l]	E
22-65-006-015 Air Compressors	4-stroke gas, exhaust	Uncontrolled	---	0.259 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.041 g/hp-hr[l]	E
22-65-006-025 Welders	4-stroke gas, exhaust	Uncontrolled	---	0.259 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.041 g/hp-hr[l]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
22-65-006-030 Pressure Washers	4-stroke gas, exhaust	Uncontrolled	---	0.259 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.041 g/hp-hr[l]	E
22-65-007-010 Shredders >5 hp	4-stroke gas, exhaust	Uncontrolled	---	0.254 g/hp-hr[l]	E
	4-stroke gas, crank case	Uncontrolled	---	0.04 g/hp-hr[l]	E
22-65-008-005 Aircraft Support Equipment	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.029 g/hp-hr[n]	E
22-65-008-010 Terminal Tractors	4-stroke gas, exhaust	Uncontrolled	---	0.13 g/hp-hr[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.029 g/hp-hr[n]	E
22-70-001-060 Specialty Vehicles Carts	Diesel, exhaust	Uncontrolled	---	0.019 g/hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hr	E
22-70-002-003 Asphalt Pavers	Diesel, exhaust	Uncontrolled	---	0.01 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0002 g/hp-hr	E
22-70-002-006 Tampers/Rammers	Diesel, exhaust	Uncontrolled	---	0.00 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.00 g/hp-hr	E
22-70-002-009 Plate Compactors	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-002-012 Concrete Pavers	Diesel, exhaust	Uncontrolled	---	0.018 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-002-015 Rollers	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-70-002-018 Scrapers	Diesel, exhaust	Uncontrolled	---	0.011 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0002 g/hp-hr[o]	E
22-70-002-021 Paving Equipment	Diesel, exhaust	Uncontrolled	---	0.016 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-002-024 Surfacing Equipment	Diesel, exhaust	Uncontrolled	---	0.00 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.00 g/hp-hr	E
22-70-002-027 Signal Boards	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-002-030 Trenchers	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-033 Bore/Drill Rigs	Diesel, exhaust	Uncontrolled	---	0.023 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-036 Excavators	Diesel, exhaust	Uncontrolled	---	0.011 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0002 g/hp-hr[o]	E
22-70-002-039 Concrete/Industrial Saws	Diesel, exhaust	Uncontrolled	---	0.023 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-042 Cement and Mortar Mixers	Diesel, exhaust	Uncontrolled	---	0.016 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-002-045 Cranes	Diesel, exhaust	Uncontrolled	---	0.02 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Mean	Factor Rating
22-70-002-048 Graders	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-051 Off-Highway Trucks	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr[o]	E
22-70-002-054 Crushing/Proc. Equipment	Diesel, exhaust	Uncontrolled	---	0.023 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-057 Rough Terrain Forklifts	Diesel, exhaust	Uncontrolled	---	0.027 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-060 Rubber Tire Loaders	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr[o]	E
22-70-002-063 Rubber Tire Dozers	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr[o]	E
22-70-002-066 Tractors/Loaders/ Backhoes	Diesel, exhaust	Uncontrolled	---	0.022 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-069 Crawler Tractors	Diesel, exhaust	Uncontrolled	---	0.02 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-002-072 Skid Steer Loaders	Diesel, exhaust	Uncontrolled	---	0.034 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0006 g/hp-hr[o]	E
22-70-002-075 Off-Highway Tractors	Diesel, exhaust	Uncontrolled	---	0.039 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0008 g/hp-hr[o]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-70-002-078 Dumpers/Tenders	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr[o]	E
22-70-002-081 Other Construction Equipment	Diesel, exhaust	Uncontrolled	---	0.023 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-003-010 Aerial Lifts	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-003-020 Forklifts	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-003-030 Sweepers/Scrubbers	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-003-040 Other General Industrial Equipment	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-003-050 Other Material Handling Equipment	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-004-040 Rear Engine Riding Mowers	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-004-055 Lawn and Garden Tractors	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-004-060 Wood Splitters	Diesel, exhaust	Uncontrolled	---	0.0192 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-70-004-065 Chippers/Stump Grinders	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-004-075 Other Lawn and Garden Equipment	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-005-015 Agricultural Tractors	Diesel, exhaust	Uncontrolled	---	0.036 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0006 g/hp-hr[o]	E
22-70-005-020 Combines	Diesel, exhaust	Uncontrolled	---	0.02 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-005-025 Balers	Diesel, exhaust	Uncontrolled	---	0.038 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0006 g/hp-hr	E
22-70-005-035 Sprayers	Diesel, exhaust	Uncontrolled	---	0.038 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0006 g/hp-hr	E
22-70-005-040 Tillers >5 hp	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-005-045 Swathers	Diesel, exhaust	Uncontrolled	---	0.014 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-005-050 Hydro Power Units	Diesel, exhaust	Uncontrolled	---	0.036 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0006 g/hp-hr	E
22-70-005-055 Other Agricultural Equipment	Diesel, exhaust	Uncontrolled	---	0.029 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0006 g/hp-hr	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a] Range[b]	Emission Factor[a] Mean	Factor Rating
22-70-006-005 Generator Sets	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-006-010 Pumps	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-006-015 Air Compressors	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-006-025 Welders	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-006-030 Pressure Washers	Diesel, exhaust	Uncontrolled	---	0.019 g/hp-hr	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr	E
22-70-007-015 Skidders	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr[o]	E
22-70-007-020 Fellers/Bunchers	Diesel, exhaust	Uncontrolled	---	0.013 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0003 g/hp-hr[o]	E
22-70-008-005 Aircraft Support Equipment	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-70-008-010 Terminal Tractors	Diesel, exhaust	Uncontrolled	---	0.025 g/hp-hr[o]	E
	Diesel, crank case	Uncontrolled	---	0.0005 g/hp-hr[o]	E
22-82-005-005 Vessels w/Inboard Engines	2-stroke gas, exhaust	Uncontrolled	---	11.358 g/gal[n]	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
22-82-005-010 Vessels w/Outboard Engines	2-stroke gas, exhaust	Uncontrolled	---	11.358 g/gal[n]	E
22-82-005-015 Vessels w/Sterndrive Engines	2-stroke gas, exhaust	Uncontrolled	---	11.358 g/gal[n]	E
22-82-005-025 Sailboat Auxiliary Outboard Engines	2-stroke gas, exhaust	Uncontrolled	---	11.358 g/gal[n]	E
22-82-010-005 Vessels w/Inboard Engines	4-stroke gas, exhaust	Uncontrolled	---	1.413 g/gal[n]	E
22-82-010-010 Vessels w/Outboard Engines	4-stroke gas, exhaust	Uncontrolled	---	1.71 g/gal[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.376 g/gal[n]	E
22-82-010-015 Vessels w/Sterndrive Engines	4-stroke gas, exhaust	Uncontrolled	---	1.413 g/gal[n]	E
22-82-010-020 Sailboat Auxiliary Inboard Engines	4-stroke gas, exhaust	Uncontrolled	---	1.413 g/gal[n]	E
22-82-010-025 Sailboat Auxiliary Outboard Engines	4-stroke gas, exhaust	Uncontrolled	---	1.71 g/gal[n]	E
	4-stroke gas, crank case	Uncontrolled	---	0.376 g/gal[n]	E
22-82-020-005 Vessels w/Inboard Engines	Diesel, exhaust	Uncontrolled	---	0.39 g/gal	E

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
22-82-020-010 Vessels w/Outboard Engines	Diesel, exhaust	Uncontrolled	---	0.39 g/gal	E
	Diesel, crank case	Uncontrolled	---	0.008 g/gal	E
22-82-020-015 Vessels w/Sterndrive Engines	Diesel, exhaust	Uncontrolled	---	0.39 g/gal	E
22-82-020-020 Sailboat Auxiliary Inboard Engines	Diesel, exhaust	Uncontrolled	---	1.959 g/gal	E
22-82-020-025 Sailboat Auxiliary Outboard Engines	Diesel, exhaust	Uncontrolled	---	1.959 g/gal	E
	Diesel, crank case	Uncontrolled	---	0.039 g/gal	E
26-10-030-000 Yard Waste	Biomass burning	Uncontrolled	---	0.40 lb/ton (0.198 g/kg)	U4
28-01-500-000 Land Clearing/Burning	Biomass burning	Uncontrolled	---	0.32 lb/ton (0.163 g/kg)	U4
28-10-001-000 Forest Fires	Fine wood	Uncontrolled	---	0.24 lb/ton (0.12 g/kg)	U4
	Small wood			0.24 lb/ton (0.12 g/kg)	U4
	Large wood (flaming)			0.24 lb/ton (0.12 g/kg)	U4
	Large wood (smoldering)			0.90 lb/ton (0.45 g/kg)	U4
	Live vegetation			0.52 lb/ton (0.26 g/kg)	U4

TABLE A-1. CONTINUED

SCC/AMS Code and Description	Emissions Source	Control Device	Emission Factor[a]		Factor Rating
			Range[b]	Mean	
28-10-001-000 Forest Fires (continued)	Duff (flaming)			0.24 lb/ton (0.12 g/kg)	U4
	Duff (smoldering)			0.90 lb/ton (0.45 g/kg)	U4
28-10-005-000 Slash (pile) Burning	Biomass burning	Uncontrolled	---	0.32 lb/ton (0.163 g/kg)	U4
28-10-015-000 Prescribed Burning (Broadcast)	Fine wood	Uncontrolled	---	0.24 lb/ton (0.12 g/kg)	U4
	Small wood			0.24 lb/ton (0.12 g/kg)	U4
	Large wood (flaming)			0.24 lb/ton (0.12 g/kg)	U4
	Large wood (smoldering)			0.90 lb/ton (0.45 g/kg)	U4
	Live vegetation			0.52 lb/ton (0.26 g/kg)	U4
	Duff (flaming)			0.24 lb/ton (0.12 g/kg)	U4
	Duff (smoldering)			0.90 lb/ton (0.45 g/kg)	U4
28-10-040-000 Rocket engine testing	Mobile	Uncontrolled	---	0.14 lb/ton (0.057 kg/Mg)	C

[a]Factors are generally expressed as lb (kg) butadiene emitted per ton (Mg) produced and tons (Mg) emitted per year, unless otherwise noted.
[b]Ranges are based on actual emissions reported by the facilities. Thus, values include controls whenever they have been implemented.
[c]Assumes production capacity of 100 percent.
[d]Assumes production capacity of 80 percent.
[e]Upper value used to prevent disclosing confidential operating capacity.
[f]Assumes production capacity of 81 percent.
[g]Only incomplete data on emissions were available, therefore, values underestimate emissions.
[h]Upper value used to prevent disclosing confidential operating capacity.
[i]Lower end of range is for one solid waste stream; upper end includes solid waste, wastewater and contaminated cooling water.
[j]Total number of components is 79,430: 60 percent flanges, 29 percent liquid valves, 8 percent gas valves, and 3 percent all others combined.
[k]Data from two facilities are specific to the emulsion process; the third is assumed to use the same.
[l]Adjusted for in-use effects using small utility engine data.
[m]Emission factors for 4-stroke propane-fueled equipment.
[n]Adjusted for in-use effects using heavy duty engine data.

TABLE A-1. CONTINUED

[o]Exhaust HC adjusted for transient speed and/or transient load operation.

"---" means no data available.

APPENDIX B

ESTIMATING METHODS FOR NATIONAL BUTADIENE EMISSION SOURCES

EMISSIONS FROM ON-ROAD MOBILE SOURCES

Basis for Calculation

To estimate national butadiene emissions for this report, the butadiene emission factor presented in the MVATS[1] was used with VMT data from the Federal Highway Administration's *Highway Statistics 1992*.[2] This approach is similar to the one used to estimate emissions from on-road mobile sources for State Implementation Plan (SIP) inventories (*Procedures for Emission Inventory Preparation Volume IV: Mobile Sources*, 1992[3]). Table B-1 summarizes 1992 VMT data and butadiene emissions estimates for each State using the OMS's composite emission factor of 0.023 g of butadiene/mile.

Example Calculation

Annual Emissions for Alabama	=	(0.023 g butadiene/VMT) x (4.5762×10^{10} VMT) x (1.10231136 ton/Mg)
	=	1,161 ton of butadiene

TABLE B-1. 1992 ON-ROAD BUTADIENE EMISSIONS

State	1992 Vehicle Miles Travelled (millions)	Emissions in tons (Mg)
Alabama	45,762	1,161 (1,053)
Alaska	3,841	97 (88)
Arizona	35,047	888 (806)
Arkansas	23,081	584 (530)
California	262,548	6,657 (6,039)
Colorado	28,927	733 (665)
Connecticut	26,459	671 (609)
Delaware	6,892	175 (159)
Dist. of Columbia	3,562	90 (82)
Florida	114,311	2,898 (2,629)
Georgia	77,904	1,975 (1,792)
Hawaii	8,066	205 (186)
Idaho	10,764	273 (248)
Illinois	87,642	2,222 (2,016)
Indiana	57,072	1,447 (1,313)
Iowa	23,926	606 (550)
Kansas	24,163	613 (556)
Kentucky	38,062	965 (875)
Louisiana	33,853	859 (779)
Maine	12,151	308 (279)
Maryland	41,896	1,063 (964)
Massachusetts	47,348	1,200 (1,089)
Michigan	84,219	2,135 (1,937)
Minnesota	41,162	1,044 (947)
Mississippi	26,239	665 (603)
Missouri	53,254	1,350 (1,225)
Montana	8,525	216 (196)

(continued)

TABLE B-1. CONTINUED

State	1992 Vehicle Miles Travelled (millions)	Emissions in tons (Mg)
Nebraska	14,621	370 (336)
Nevada	10,897	277 (251)
New Hampshire	10,067	256 (232)
New Jersey	59,410	1,506 (1,366)
New Mexico	18,452	467 (424)
New York	109,881	2,786 (2,527)
North Carolina	67,538	1,712 (1,553)
North Dakota	6,072	154 (140)
Ohio	95,221	2,414 (2,190)
Oklahoma	35,119	891 (808)
Oregon	27,926	708 (642)
Pennsylvania	89,200	2,262 (2,052)
Rhode Island	7,676	195 (177)
South Carolina	35,049	888 (806)
South Dakota	7,218	183 (166)
Tennessee	49,994	1,268 (1,150)
Texas	163,329	4,141 (3,757)
Utah	16,307	413 (375)
Vermont	6,019	152 (138)
Virginia	63,447	1,608 (1,459)
Washington	49,386	1,252 (1,136)
West Virginia	16,478	418 (379)
Wisconsin	47,628	1,207 (1,095)
Wyoming	6,217	158 (143)
Total	2,239,828	56,786 (51,517)

Source: Reference 2.

EMISSIONS FROM NON-ROAD MOBILE SOURCES

Basis for Calculation:

National emissions for butadiene were taken directly from the NEVES report.[4] "In use" estimates for butadiene were taken from two inventories: A, which is an EPA-developed inventory; and B, which is an inventory prepared by trade associations. The values were averaged to calculate the national emission estimates.

Calculation:

Butadiene estimate for the:

A inventory - 47,816 tons/year

B inventory - 35,949 tons/year

$$\text{National Annual Emissions} = \frac{47{,}816 + 35{,}949}{2}$$

$$= 41{,}883 \text{ tons/year}$$

EMISSIONS FROM AIRCRAFT

Basis for Calculation

To estimate national emissions from aircraft, hydrocarbon emission indices for representative fleet mixes are provided in the emissions inventory guidance document *Procedures for Emissions Inventory Preparation; Volume IV: Mobile Sources*.[5] The hydrocarbon emission indices are 0.394 pounds per LTO (0.179 kg per LTO) for general aviation and 1.234 pounds per LTO (0.560 kg per LTO) for air taxis.

The butadiene fraction of the hydrocarbon total can be estimated by using the percent weight factors from SPECIATE.[6] It is assumed in this report that half of the general aviation fleet is equipped with piston engines and the other half is equipped with turbine engines, such that these two emission factors are averaged. Because air taxis have larger engines and more of the fleet is equipped with turboprop and turbojet engines than is the general aviation fleet, the percent weight factor is somewhat different from the general aviation emission factor. To approximate a butadiene percent weight factor for air taxis, the commercial and general aviation (piston) percent weight factors were averaged.

Because there are no aggregated hydrocarbon emission indices for commercial or military aircraft, national emissions estimates for butadiene for these aircraft categories cannot be estimated without considerable detailed activity data (i.e., fleet mix and associated LTOs).

To estimate national butadiene emissions for general aviation and air taxis, FAA air traffic activity data[7] (LTO) were applied to the hydrocarbon emission indices to estimate total national hydrocarbon emissions. The appropriate weight percent butadiene factor were applied to the total national hydrocarbon emission values, yielding the national butadiene emission estimate for general aviation and air taxis. These emission estimates are presented in Table 6-6. Note that in this approach emissions were estimated for aircraft airport activity only; in-flight emissions cannot be calculated without considerable detailed data. In addition, this estimate does not include any aircraft activity occurring at non-FAA control towered airports.

Calculation - General Aviation

General Aviation Emissions	=	(0.394 lbs hydrocarbon/LTO) x (ton/2,000 lbs) x (19,584,898 LTOs in 1993) x (1.57 weight % butadiene)
	=	61 tons

Calculation - Air Taxis

Air Taxi Emissions	=	(1.234 lbs hydrocarbon/LTO) x (ton/2000 lbs) x (4,418,836 LTOs in 1993) x (1.69 weight % butadiene)
	=	46 tons

Calculation - Total

National Butadiene Emissions Estimate	=	61 ton/yr of butadiene + 46 ton/yr of butadiene
	=	107 ton/yr of butadiene

EMISSIONS FROM BUTADIENE PRODUCTION

Basis for Calculation

The 1992 TRI data were used as an estimate of national emissions from butadiene production facilities.[8] The TRI butadiene values (in lb/yr) reported by the 11 butadiene production facilities listed in Table 4-1 of this document were summed to give an estimate of the butadiene emissions from production facilities nationwide. The estimated national emissions of butadiene from butadiene production facilities are 191 tons/yr (163 Mg/yr).

EMISSIONS FROM MAJOR BUTADIENE USERS

Basis for Calculation

The 1992 TRI data were used to estimate national emissions from major butadiene users.[8] All facilities with their primary SIC Codes reported as 28XX, industries within the Chemicals and Allied Products classification, were assumed to represent major users of butadiene. Some of the miscellaneous butadiene uses described in Section 7.0 may also be included, but because differentiating would be difficult and the contribution to national emissions from the miscellaneous uses is considered to be small, extracting these from the TRI data was not done.

The facility SIC Codes reported included the following:

28	Chemicals and allied products
2812	Alkalies and chlorine
2819	Industrial inorganic chemicals, nec
2821	Plastics materials, synthetic resins, and nonvulcanizable elastomers
2822	Synthetic rubber (vulcanizable elastomers)
2865	Cyclic organic crudes and intermediates, and organic dyes and pigments
2869	Industrial organic chemicals, nec
2879	Pesticides and agricultural chemicals, nec
2891	Adhesives and sealants
2899	Chemicals and chemical preparations, nec

To avoid double-counting butadiene production facility emissions (butadiene production facilities also fall under the 2869 SIC Code), the total for the 11 facilities (191 tons/yr (163 Mg/yr)) was subtracted from the total for the 28XX SIC Codes (1,596 tons/yr (1,448 Mg/yr)). The estimated national emissions of butadiene from major butadiene users are 1,405 tons/yr (1,275 Mg/yr).

EMISSIONS FROM MISCELLANEOUS OTHER BUTADIENE SOURCES

Basis for Calculation

The 1992 TRI data also included other source categories that were not otherwise identified as butadiene sources during the revision of this document.[8] These facilities fall into one of the following SIC Codes. There were two facilities for which no SIC Code was reported, and one facility used an SIC Code, 2641, for which the 1987 Standard Industrial Classification Manual[9] has no description.

2046 Wet corn milling
2369 Girl's, children's, and infant's outerwear, nec
2621 Paper mills
3312 Steel works, blast furnaces (including coke ovens), and rolling mills
3579 Office machines, nec
8731 Commercial physical and biological research

The butadiene emissions reported by each of these facilities were summed to total national emissions of butadiene from miscellaneous other butadiene sources of 106 tons/yr (96 Mg/yr).

EMISSIONS FROM PETROLEUM REFINING

Basis for Calculation

While the Petroleum Refineries NESHAP provides emissions estimates for VOCs and total HAPs at 190 facilities, emission estimates are not available for specific HAPs, such as butadiene.[10] Therefore, 1992 TRI data were used as estimates of national emissions from petroleum refining.[8] Petroleum refining is represented by SIC Code 2911. Based on the TRI data, the estimated national emissions of butadiene from petroleum refining are 219 tons/yr (241 Mg/yr).

EMISSIONS FROM SECONDARY LEAD SMELTING

Basis for Calculation

As part of the background information for developing the proposed and final NESHAP for the secondary lead smelting industry, emissions data were collected for 1,3-butadiene and other species of organic HAP during an EPA-sponsored test program at three representative smelters.[11] These data were used to calculate total controlled organic HAP emissions for each of the 23 secondary lead smelters known to exist in the United States.

The emission estimates assumed that organic HAP emissions from each smelter were controlled to the level required by the final NESHAP. Total estimated organic HAP emissions from this industry under the final NESHAP are 552 ton/yr (508 Mg/yr). The final NESHAP will reduce organic HAP emissions 71 percent from a 1990 baseline of 1,905 ton/yr (1,728 Mg/yr).

The emissions test data were also used to estimate a ratio of 1,3-butadiene to total organic HAP emissions for each of the three smelters for which test data were available:

	ton 1,3-butadiene/ton organic HAP
East Penn Manufacturing Company:	0.337
Schuylkill Metals:	0.252
Tejas Resources:	0.131
Average:	0.240

The data from East Penn and Schuylkill are from blast furnaces and the data from Tejas are from a rotary furnace. The difference in ratios cannot be explained by any of the parameters that were monitored during the testing program or any of the differences in feed stocks used at these smelters; all three smelters used essentially the same feed stocks.

Example Calculation

National Emissions Estimate	=	(0.240 tons of 1,3-butadiene/ton organic HAP) x (560 tons organic HAP/yr)
	=	134.4 ton/yr (121.9 Mg/yr)

EMISSIONS FROM OPEN BURNING OF BIOMASS

Basis for Calculation

Emission factors for butadiene emissions from forest fires and prescribed burning were obtained from a 1993 Office of Research and Development project on Puget Sound and an inventory prepared by Darold Ward and Janice Peterson for the USDA Forest Service.[12,13] The emission factors vary according to fuel type (i.e., flaming versus smoldering wood or duff or live vegetation) and are presented in Section 7.0 of this document.

A national activity level for biomass burning (i.e., prescribed burning and forest fires) was obtained from a final report for the national emission inventories compiled for Section 112(c)(6) pollutants, prepared by Radian Corporation for the EPA.[14] The total biomass burning in prescribed burning was documented as 42 million tons, and the total biomass burned in forest fires was documented as 53 million tons.[14] Because no information was available to characterize, on a national basis, the percentages of the specific types of fuels burned in forest fires and prescribed burning, certain assumptions were made in calculating national emissions from the emission factors. The national estimate is calculated based on flaming wood and duff and smoldering wood and duff. It was assumed that, on a national basis, during prescribed burns and forest fires 75 percent of the biomass (wood and duff) is burned under flaming conditions and 25 percent of the biomass (wood and duff) is burned under smoldering conditions.

The following calculations were carried out to determine national butadiene emissions from forest fires. However, the national emissions from prescribed burning were obtained from a prescribed fire emissions inventory developed from Ward and Peterson's methodology.[13]

Example Calculation:

Annual	=	emissions from forest fires
National Emissions	=	[(1.2 x 10^{-4} tons/ton flaming wood and duff burned) x (39,750,000 tons flaming wood and duff burned in forest fires/yr)] +
		[(4.5 x 10^{-4} tons/ton smoldering wood and duff burned) x (13,250,000 tons smoldering wood and duff burned in forest fires/yr)]
	=	10,733 tons/yr (9,737 Mg/yr)
Annual	=	emissions from prescribed burning
National Emissions	=	9,198 tons/yr (8,345 Mg/yr)
Annual	=	emissions from biomass burning
National Emissions	=	10,733 tons/yr + 9,198 tons/yr
	=	19,931 tons/yr (18,082 Mg/yr)

REFERENCES

1. U.S. EPA. *Motor Vehicle-Related Air Toxics Study*. Section 7.0 - 1,3-Butadiene. EPA-420-R-93-005. Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, 1993. pp. 7-1 to 7-7.

2. U.S. Department of Transportation. *Highway Statistics*. Washington, D.C.: Federal Highway Administration, 1993. p. 208

3. U.S. EPA. *Mobile Sources Procedures for Emission Inventory Preparation*, Volume IV: Mobile Sources. EPA-450/4-81-026d (Revised). Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, 1992. p. 176.

4. U.S. EPA. *Non-Road Engine and Vehicle Emission Study*. 21A-2001. Washington, D.C.: U.S. Environmental Protection Agency, Office of Air and Radiation, 1991. pp. M-53, O-53.

5. U.S. EPA. *Mobile Sources Procedures for Emission Inventory Preparation*, Volume IV: Mobile Sources. Section 5.0 - Emissions from Aircraft. EPA-450/4-81-026d (Revised). Ann Arbor, Michigan: U.S. Environmental Protection Agency, Office of Mobile Sources, 1992. p. 176.

6. U.S. EPA. *Volatile Organic Compound/Particulate Matter Speciation Data System (SPECIATE)*. Version 1.5. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, October 1992.

7. Federal Aviation Administration. *Air Traffic Activity*. Office of Management Systems, 1993. Table 1-7.

8. U.S. EPA. *1992 Toxic Chemical Release Inventory (SARA 313) Database*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Toxic Substances, 1993.

9. U.S. Executive Office of the President. *Standard Industrial Classification Manual*. Washington, D.C.: Government Printing Office, Office of Management and Budget, 1987.

10. Zarate, M. (Radian Corporation). Memorandum to J. Durham (U.S. Environmental Protection Agency) concerning "Process Vent Information Collection Request Data Quality Analysis," August 25, 1993.

11. U.S. EPA. *Final Background Information Document for Secondary Lead NESHAP*. EPA-450/R-94-024a. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, June 1994.

12. Campbell, D.L. and J. Mangino (Radian Corporation). "Evaluation and Improvement of the Puget Sound Toxic Air Contaminants Emissions Inventory." Technical Note. EPA Contract No. 68-D1-0031. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, May 1994.

13. Peterson, J. and D. Ward. *An Inventory of Particulate Matter and Air Toxic Emissions from Prescribed Fires in the United States for 1989*. U.S. Department of Agriculture, Forest Service, 1989. pp. 1-16.

14. Radian Corporation. Draft final memorandum to U.S. Environmental Protection Agency concerning Inventory Plan for Section 112(c)(6) Pollutants. September 23, 1993.

APPENDIX C

FACILITY-SPECIFIC EMISSIONS DATA FROM EPA SECTION 114 RESPONSES

APPENDIX C
FACILITY-SPECIFIC EMISSIONS DATA
FROM EPA SECTION 114 RESPONSES

Tables C-1 through C-25 contain the capacity and emissions data that formed the basis for the emission factor ranges and ranges of annual emissions presented in the main text. Capacity data were compiled from responses to Section 114 requests or literature values if available. Most of the emissions data are from responses to Section 114 requests in 1984. Inconsistencies with the text are due to facility changes in ownership and/or in the production process since 1984. The emission values, therefore, may no longer reflect the current status of the industry. Furthermore, reported emissions were not supplied for every emission point identified, nor were all emission points identified by each facility.

Emission factors for each emission point were calculated by dividing the reported emissions by the facility's capacity, modified to reflect actual production. In instances where the use of facility production capacity in an emission factor might reveal company-confidential information, the emissions data were not used to calculate the ranges. In the absence of facility-reported capacity values, literature values may have been used.

Equipment leak emission estimates were derived from 1984 data supplied by facilities in Section 114 responses. Using the procedure described in Appendix D and average CMA emission factors, ranges of annual emissions were calculated. Equipment count data for the miscellaneous category were unavailable, therefore estimates are based on the SOCMI emission factors as reported in the summary memoranda.

TABLE C-1. BUTADIENE PRODUCTION FACILITIES FOR WHICH 1984 EMISSION DATA ARE AVAILABLE

Company	Location	Capacity in 1984 tons/yr (Mg/yr)
Amoco Chemicals Company	Chocolate Bayou, TX	90,400 (82,000)[a]
	Channelview, TX	350,500 (318,000)
Cain Chemical Company[b]	Chocolate Bayou, TX	67,200 (61,000)[a]
Cain Chemical Company[c]	Corpus Christi, TX	110,200 (100,000)[a]
Exxon Chemicals Company	Baton Rouge, LA	155,400 (141,000)
	Baytown, TX	120,200 (109,000)
Mobil Chemical Company	Beaumont, TX	29,800 (27,000)[a]
Shell Chemical Company	Deer Park, TX	400,100 (363,000)
	Norco, LA	250,200 (227,000)
Texas Chemical Company	Port Neches, TX	179,700 (163,000)
Texas Petrochemicals Corp.	Houston, TX	400,100 (363,000)[d]

Source: Reference 1.

[a]Values taken from the literature.
[b]Formerly DuPont de Nemours and Company.
[c]Formerly El Paso Products Company.
[d]250,200 tons/yr (227,000 Mg/yr) from the recovery process, 149,900 tons/yr (136,000 Mg/yr) from the dehydrogenation process.

TABLE C-2. BUTADIENE EMISSIONS (1984) FROM PROCESS VENTS AT OLEFINS AND BUTADIENE PRODUCTION FACILITIES [1]

	C_4 Stream Production Emissions in tons/yr (Mg/yr)[a]			Recovery Process Emissions in tons/yr (Mg/yr)[b]		
Company	Uncontrolled	Controlled	Control Device	Uncontrolled	Controlled	Control Device
Facility A	---	---	---	---	---	Flare
Facility B	---	---	Flare	---	---	Flare
Facility C	---	---	---	---	---	Flare
Facility D	0.3 (0.3)	N/A	None	---	---	---
Facility E	---	---	---	1.5 (1.4)	N/A	None
Facility F	---	---	---	---	---	Flare
Facility G	---	---	---	67.7 (61.4)	0.7 (0.6)	Boiler/Flare
Facility H[d]	---	---	---	68.8 (62.4)	5.5 (5.0)	Boiler/Flare

Source: Reference 1.

[a]C_4 stream production means production of a mixed-C_4 stream as a coproduct from the manufacturer of ethylene and other alkenes in an olefins plant.
[b]Recovery process means recovery of butadiene from a mixed-C_4 stream.
[c]The combination was assigned an overall efficiency of 99 percent.
[d]Source of the mixed-C_4 stream is unknown.
[e]Reduction efficiency based on facility reported information.

"---" means no data available.
N/A means not applicable.

TABLE C-3. SUMMARY OF BUTADIENE EMISSIONS (1987) FROM EQUIPMENT LEAKS AT NINE PRODUCTION FACILITIES

Equipment Component	Number of Components	Emissions[a]	
		(tons/yr)	(Mg/yr)
Pumps - liquid	376	74	67
Compressors	17	0.0002	0.0002
Flanges	47,277[b]	51	46
Valves - gas	6,315	24	22
Valves - liquid	23,233	260	230
Pressure relief devices	428	45	41
Open-ended lines	1,744	0.73	0.67
Sample points[c]	40	0.37	0.34
Total:	79,430	460	410

[a]Assumes 80 percent of production capacity (taken as 8,760 hours of operations per year). Emissions rounded to two significant figures.

[b]Although only 11,428 flanges were included in the study, a ratio of 1.6:1 flanges:valves is generally accepted. The total number of flanges upon which the emissions estimate is based is, therefore, [(6,315 + 23,233) x 1.6] = 47,277.

[c]Emission factor was taken from reference 1, p.5-16.

TABLE C-4. BUTADIENE EMISSIONS (1984) FROM SECONDARY SOURCES AT BUTADIENE PRODUCTION FACILITIES USING THE RECOVERY FROM A MIXED-C_4 STREAM PROCESS [1]

Company	Emissions in tons/yr (Mg/yr)		Controls/Destination	
	Wastewater	Solid Waste	Wastewater	Solid Waste
Facility B	Negligible	Negligible[a]	---	---
Facility D	6.1 (5.5)	---	Emissions routed to flare, air strip or steam strip	Incineration
Facility E	0.03 (0.03)	Negligible	Emissions routed to flare, air strip or steam strip for recovery or to flare	Incineration[b]
Facility G	---	---	Onsite NPDES, disposal wells	Offsite landfill
Facility H	18.1 (16.4)	---	Aeration lagoon	Offsite landfill
Facility I	0.18 (0.16)	---	Biological treatment	---
Facility J	320 (290)	---	Biological treatment, discharge	---
Facility K	---	---	Biological treatment	Landfill, disposal well

Source: Reference 1.

[a]Reported as "minor."
[b]Estimated at 4.43 x 10^{-5} lb/yr (3.99 x 10^{-5} Mg/yr).

"---" means no data available.

TABLE C-5. STYRENE-BUTADIENE ELASTOMER AND LATEX PRODUCTION FACILITIES FOR WHICH 1984 EMISSIONS DATA ARE AVAILABLE

Company	Location	Capacity in 1984 tons/yr (Mg/yr)
Elastomer		
American Synthetic[a]	Louisville, KY	111,200[b] (100,000)[b]
B. F. Goodrich[c]	Port Neches, TX	[d]
Copolymer Rubber	Baton Rouge, LA	232,600[b] (211,000)[b]
Firestone	Lake Charles, LA	132,300[b] (120,000)[b]
GenCorp	Odessa, TX	95,900[b] (87,000)[b]
Goodyear	Houston, TX	[d]
Uniroyal[c]	Port Neches, TX	201,700[b] (183,000)[b]
Latex		
Borg-Warner[e]	Washington, WV	[d]
Dow Chemical	Dalton, GA	[d]
Dow Chemical	Freeport, TX	[d]
Dow Chemical	Gates Ferry, CT	[d]
Dow Chemical	Midland, MI	[d]
Dow Chemical	Pittsburgh, CA	[d]
GenCorp	Mogadore, OH	66,100 (60,000)
Goodyear[e]	Akron, OH	[d]
Goodyear	Calhoun, GA	[d]
W. R. Grace	Owensboro, KY	3,300 (3,000)
Polysar	Chattanooga, TN	167,500 (152,000)
Reichhold (DE)	Cheswold, DE	65,000 (59,000)
Reichhold (GA)	Kensington, GA	58,400 (53,000)
Unocal	La Mirada, CA	19,800 (18,000)

Source: Reference 2.

[a]Facility was mothballed in 1984.
[b]Dry weight.
[c]B.F. Goodrich and Uniroyal are now Ameripol Synpol.
[d]Company-confidential.
[e]Facility's operating status in 1988 unknown.

TABLE C-6. BUTADIENE EMISSIONS (1984) FROM PROCESS VENTS AT SB COPOLYMER PRODUCTION FACILITIES[2]

Company	Vent Location	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Elastomer					
Facility A	Recovery process	29 (26)	2.9 (2.6)	Absorber	90
Facility B	Butadiene recovery	463 (420)	23.1 (21.0)	Kerosene absorber	95
Facility C	Butadiene absorber vent	22 (20)	0.02 (0.02)[a]	Boiler[a]	99.9
Facility D	Tank farm, purification reactor, desolventization	88 (80)[b]	1.8 (1.6)[b]	Flare	98[c]
Facility E	Recovery area absorber vent	4.7 (4.3)	0.7 (0.6)	Absorber	86
Facility F	Process vessels (storage blending, coagulation, crumb washing)	66 (60.0)[a]	N/A	None	0
	Dryers	11 (10.0)[a]	N/A	None	0
Facility G	Butadiene recovery	139 (126)	7.0 (6.3)[b]	Kerosene scrubbers[b]	95
Latex					
Facility H	Latex A1	127 (115)	N/A	None	0
	Latex A2	127 (115)	N/A	None	0
	Latex B	518 (469.8)	44.5 (40.4)	Pressure condenser	91.4
Facility I	Vent stack	[d]	285 (259)	[d]	[d]
Facility J	Monomer mix tanks, recovery tank	[d]	11.4 (10.3)	[d]	[d]

TABLE C-6. CONTINUED

Company	Vent Location	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Elastomer					
Facility K	Reactors, strippers	[d]	10.8 (9.8)	[d]	[d]
Facility L	Process scrubber	[d]	30.0 (27.0)	[d]	[d]
	Latex process	[d]	5.3 (4.8)		
Facility M	Latex process and tanks	[d]	5.6 (5.1)	[d]	[d]
Facility N	Central vacuum flare stack	628 (570)	12.6 (11.4)	Flare	98
	Latex stripping	0.6 (0.5)	N/A	None	0
Facility O	Butadiene recovery	36 (33)	3.7 (3.3)	Condenser	90
Facility P	Vent gas absorber	17 (15)	0.3 (0.3)	Scrubber	98
Facility Q	Reactor	104.7 (95.0)	N/A	None	0
	Mix tank	20.1 (18.2)	N/A	None	0
Facility R	Reactor recovery storage	5.5 (5.0)	0.1 (0.1)	Flare[e]	98
	Recycle butadiene receiver	15.4 (14.0)	N/A[e]	None	0
	Stripping vacuum pump exhaust	45.0 (40.8)	N/A	None	0
Facility S	Process	325 (295)	6.5 (5.9)	Flare	98

TABLE C-6. (CONTINUED)

Company	Vent Location	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Elastomer					
Facility T	Waste vent gas	60 (54.0)	N/A	None	0
	Vacuum pump discharge	226.3 (205.3)	N/A	None	0
	Stream jet discharge	11.9 (10.8)	N/A	None	0
Facility U	Unknown	Unknown	Unknown	Incineration	Unknown

Source: Reference 2.

[a]Emissions shown are for both SB copolymer and nitrile rubber production.
[b]Emissions shown are for both SB copolymer and polybutadiene production.
[c]Facility reported a higher efficiency but did not support it with test data.
[d]Information for facilities on control devices is considered confidential.
[e]Estimates exclude reported emissions for pressure relief discharges of 0.1 tons/yr (0.1 Mg/yr).

N/A = not applicable.

TABLE C-7. BUTADIENE EMISSIONS (1984) FROM EQUIPMENT LEAKS AT SB COPOLYMER PRODUCTION FACILITIES

Company	Uncontrolled Emissions[a] tons/yr (Mg/yr)	Control Status
Elastomer		
Facility A	6.2 (5.6)	PRDs vented to a flare
Facility B	8.5 (7.7)	Rupture discs for PRDs
Facility C	14.3 (13)[b]	Rupture discs
Facility D	4.0 (3.6)	Rupture discs and flare for PRDs
Facility E	74 (67)	None reported
Facility F	23 (21)[b]	Rupture discs and flare for PRDs
Facility G	14 (13)[c]	Most PRDs have rupture discs vented
Latex		
Facility H	15 (14)	None reported
Facility I	5.0 (4.5)	None reported
Facility J	1.5 (1.4)	None reported
Facility K	0.98 (0.89)	None reported
Facility L	2.9 (2.6)	Some rupture discs
Facility M	2.1 (1.9)	Rupture discs
Facility N	5.8 (5.3)	None reported
Facility O	4.6 (4.2)	Rupture discs for PRDs
Facility P	4.7 (4.3)	None reported
Facility Q	0.11 (0.10)	None reported
Facility R	14 (13)	Some rupture discs
Facility T	2.2 (2.0)	Most PRDs have rupture discs

Source: References 2 and 3.

[a]Calculated using 1984 equipment counts and average CMA emission factor. Emissions rounded to two significant figures.
[b]The emissions are for both SB copolymer and nitrile rubber production.
[c]The emissions are for both SB copolymer and polybutadiene production.

PRDs= Pressure relief devices.

TABLE C-8. BUTADIENE EMISSIONS (1984) FROM SECONDARY SOURCES AT SB COPOLYMER PRODUCTION FACILITIES[2]

	Emissions in tons/yr (Mg/yr) from:			
Company	Wastewater	Other Liquid Waste	Solid Waste	Waste Treatment
Elastomer				
Facility A	0	0	0	None
Facility B	0.4 (0.4)	---	---	Landfill, primary and secondary treatment
Facility C	0.9 (0.8) [a]	[a] ---	0.0007 (0.0006) [a]	Biotreatment[a], incineration, landfill
Facility D	0	0	0	Unknown
Facility E	13.8 (12.5) [a]	[a] ---	2.2 (2.0) [a]	Biotreatment[a], landfill
Facility G	0	---	0	Unknown
Latex				
Facility H	0	0	0	Unknown
Facility I	0	---	0	NPDES permit, landfill
Facility J	0	---	0	Unknown
Facility K	0	0.008 (0.007)	0 [b]	Biotreatment[b] incineration of liquid waste, landfarm solids
Facility L	0	---	0	Biotreatment, landfill
Facility M	0	---	---	Solar pond
Facility N	0.00002 (0.00002)	---	---	Equalization, settling, discharge to POTW

TABLE C-8. CONTINUED

Company	Emissions in tons/yr (Mg/yr) from: Wastewater	Other Liquid Waste	Solid Waste	Waste Treatment
Elastomer				
Facility O	14.4 (13.1)[c] [c]	[c]	[c]	Discharge to POTW
Facility P	8.6 (7.8)	---	---	Aerated lagoon
Facility Q	Negligible[d]	---	---	Biotreatment, aerated lagoon
Facility R	26.4 (24.0)	---	---	City sewer
Facility T	Negligible[d]	Negligible[d]	Negligible[d]	Biotreatment

Source: Reference 2.

[a]Emissions are for both SB copolymer and nitrile rubber production.
[b]Emissions occur off-site from an incinerator stack.
[c]Facility did not report emissions separately for each of the four production processes on-site.
[d]Only trace amounts of butadiene reported in waste.
[e]Facility had two units in production; waste treatment at Unit #2 is confidential.

"---" means no information available on the source.

TABLE C-9. POLYBUTADIENE PRODUCTION FACILITIES FOR WHICH 1984 EMISSIONS DATA ARE AVAILABLE

Company	Location	Capacity in 1985 tons/yr (Mg/Yr)
American Synthetic Rubber	Louisville, KY	69,400[a] (63,000)[a]
Arco Chemical[b]	Channelview, TX	7,500 (6,800)
Borg-Warner	Ottawa, IL	[c]
Firestone	Orange, TX and Lake Charles, LA[d]	121,300[a] (110,000)[a]
Goodyear	Beaumont, TX	[c]
Phillips	Borger, TX	70,500[a] (64,000)[a]
Polysar	Orange, TX	[c]

Source: Reference 4.

[a]Value taken from the literature.
[b]Facility's operating status in 1988 unknown.
[c]Company confidential.
[d]Facility coproduced SBS elastomer and polybutadiene rubber, but was primarily dedicated to SB elastomer.

TABLE C-10. BUTADIENE EMISSIONS (1984) FROM PROCESS VENTS AT POLYBUTADIENE PRODUCTION FACILITIES[4]

Company	Vent Locations	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Facility A	Recovery process	0.09 (0.08)	0.002 (0.002)	Butadiene absorber, flare	97.5
Facility B	Acetone column vent	36.5 (33.1)	N/A	None	N/A
	Vacuum system vent	73.0 (66.2)	N/A	None	N/A
Facility C	Flashers	48.9 (44.4)	4.4 (4.0)	Butadiene recovery	91
Facility D	Plantwide	22.0 (20)	0.4 (0.4)	Flare	98
Facility E	Two plant vents	568 (515)	11.4 (10.3)	Flare	98
Facility F	Polymerization reactors	5.5 (5)	0.1 (0.1)	Flare	98
	Kerosene scrubbing	27.6 (25)	0.6 (0.5)	Flare	98

Source: Reference 4.

[a]Company reported greater than 98-percent control efficiency, but did not provide supporting test data.

N/A = not applicable.

TABLE C-11. BUTADIENE EMISSIONS (1984) FROM EQUIPMENT LEAKS AT POLYBUTADIENE PRODUCTION FACILITIES

Company	Uncontrolled Emissions tons/yr (Mg/Yr)[a]
Facility A	4.1 (3.7)
Facility B	5.8 (5.3)
Facility D	32.0 (29)
Facility E	10.5 (9.5)
Facility F	5.7 (5.2)
Facility G	4.9 (4.4)

Source: References 3 and 4.

[a]Calculated using 1984 equipment counts and average CMA emission factors. Emissions rounded to two significant figures.

TABLE C-12. BUTADIENE EMISSIONS (1984) FROM SECONDARY SOURCES AT POLYBUTADIENE PRODUCTION FACILITIES

	Source tons/yr (Mg/yr)		
Company	Wastewater	Solid Waste	Waste Treatment
Facility B	---	0	Landfill
Facility C	0	---[a]	Activated sludge
Facility F	21.3 (19.3)	---	Lagoon

Source: Reference 4.

[a]Facility listed solid waste as a source but provided no data.

"---" means no data available.

TABLE C-13. ADIPONITRILE PRODUCTION FACILITIES FOR WHICH 1984 EMISSIONS DATA ARE AVAILABLE

Facility	Location	Capacity in 1984 tons/yr (Mg/Yr)
DuPont	Orange, TX	231,500 (210,000)[a]
DuPont	Victoria, TX	146,500 (132,900)

Source: Reference 5.

[a]Value taken from the literature.

TABLE C-14. BUTADIENE EMISSIONS (1984) FROM PROCESS VENTS AT ADIPONITRILE PRODUCTION FACILITIES[5]

Company	Vent Location	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Facility A	Recycle purge	540.1 (490)	10.8 (9.8)	Flare	98
	Butadiene dryer	---	---	Boiler	---
Facility B	Recycle purge	363.8 (330)	7.3 (6.6)	Flare	98
	Butadiene dryer	4.9 (4.4)	0.004 (0.004)	Boiler	99.9
	Jets	---	---	Boiler	99.9
	Second reactor	---	---	Boiler	99.9
	Refining	---	---	Boiler	99.9

Source: Reference 5.

[a]Facility reported a higher efficiency but did not provide supporting test data.

"---" means no data available.

TABLE C-15. BUTADIENE EMISSIONS (1984) FROM EQUIPMENT LEAKS AT ADIPONITRILE PRODUCTION FACILITIES

Company	Uncontrolled Emissions tons/yr (Mg/yr)[a]	Controls
Facility A	5.3 (4.8)	Ambient monitoring,[b] double mechanical seals, some PRDs routed to a flare.
Facility B	2.8 (2.5)	Quarterly LDAR, ambient monitoring, double mechanical seals.

Source: References 3 and 5.

[a]Calculated using 1984 equipment counts and average CMA emission factors. Emissions rounded to two significant figures.
[b]Ambient monitoring in the vicinity was being used to detect elevated VOCs, potentially indicating leaks.

PRDs = pressure relief devices.
LDAR = leak detection and repair program.

TABLE C-16. BUTADIENE EMISSIONS (1984) FROM SECONDARY SOURCES AT ADIPONITRILE PRODUCTION FACILITIES

Facility	Source Description	Uncontrolled Emissions tons/yr (Mg/Yr)
Facility A	Waste tank	2.2 (2.0)
	Butadiene separator blowdown water	---
Facility B	Sump tank[a]	---
	Waste liquids[a]	---
	Wastewater	1.0 (0.9)

Source: Reference 5.

[a]Source was routed to a boiler with a 99.9-percent reduction efficiency.

"---" means no data reported.

TABLE C-17. CHLOROPRENE/NEOPRENE PRODUCTION FACILITIES FOR WHICH 1984 EMISSIONS DATA ARE AVAILABLE

Company	Capacity in 1985[a] tons/yr (Mg/Yr)
Denka	37,500 (34,000)
DuPont	47,400 (43,000)

Source: Reference 6.

[a]Values taken from the literature.

TABLE C-18. BUTADIENE EMISSIONS (1984) FROM NEOPRENE PRODUCTION FACILITIES[6]

Company	Vent Location	Process Vent Emissions tons/yr (Mg/yr)		Control Device	Control Efficiency (%)	Equipment Leaks - Uncontrolled[a] tons/yr (Mg/yr)
		Uncontrolled	Controlled			
Facility A	DCB refining	5.3 (4.8)	N/A	None	0	1.03 (0.93)
	DCB refining	0.96 (0.87)	0.1 (0.1)	Absorber/-20°F condenser	88.6	
	DCB refining	1.06 (0.96)	0.6 (0.5)	-20°F condenser	48.0	
Facility B	DCB refining	176 (160)	N/A	Water-cooled condenser	0	4.9 (4.4)
	DCB synthesis	397 (360)	7.9 (7.2)	Flare	98	

Source: Reference 6.

[a]Calculated using 1984 equipment counts and average CMA emission factors. Emissions rounded to two significant figures.
[b]Company estimated a higher efficiency but did not provide supportive data.

N/A = Not applicable.

TABLE C-19. ACRYLONITRILE-BUTADIENE-STYRENE RESIN PRODUCTION FACILITIES FOR WHICH 1984 EMISSIONS DATA ARE AVAILABLE

Company	Location	Capacity in 1985[a] tons/yr (Mg/Yr)
Goodyear[b]	Akron, OH	165 (150)
Monsanto	Addyston, OH	177,500 (161,000)
Monsanto	Muscatine, IA	57,500 (52,200)

Source: Reference 7.

[a]Values taken from the literature.
[b]Goodyear coproduced ABS with nitrile elastomer. About 3 percent was dedicated to production.

TABLE C-20. BUTADIENE EMISSIONS (1984) FROM ABS PRODUCTION FACILITIES[7]

Company	Vent Location	Process Vent Emissions tons/yr (Mg/yr)		Control Device	Control Efficiency (%)	Equipment Leaks - Uncontrolled tons/yr (Mg/yr)
		Uncontrolled[a]	Controlled			
Facility A	Spray dryer	0.9 (0.8)	N/A	None	0	Unknown
	Dewatering (1)	Unknown	N/A	None	0	
Facility B	Polymerization (9)	661 (500)	0.6 (0.5)	Flare	99.9	3.5 (3.2)
	Dewatering (1)	<11 (<10)	<0.01 (<0.01)	Boiler	99.9	
	Dewatering (1)	2.1 (1.9)	N/A	None	0	
	Dewatering (1)	2.1 (1.9)	N/A	None	0	
	Tanks (3)	10.0 (9.0)	N/A	None	0	
	Tanks (6)	Unknown	Unknown	Unknown	Unknown	
	Coagul/Wash (7)	Unknown	Unknown	Unknown	Unknown	
	Compounding (9)	0	N/A	None	0	
Facility C	Polymerization (1)	276 (250)	2.8 (2.5)	Flare	99	1.2 (1.1)
	Polymerization (1)	6.8 (6.2)	N/A	None	0	

(Continued)

TABLE C-20. CONTINUED

Company	Vent Location	Process Vent Emissions tons/yr (Mg/yr) Uncontrolled[a]	Process Vent Emissions tons/yr (Mg/yr) Controlled	Control Device	Control Efficiency (%)	Equipment Leaks - Uncontrolled tons/yr (Mg/yr)
	Coagul/Wash (2)	18.5 (16.8)	N/A	None	0	
	Dewatering (4)	10.7 (9.7)	N/A	None	0	
	Compounding (1)	6.9 (6.3)	N/A	None	0	
	Tanks (5)	6.2 (5.6)	N/A	None	0	

Source: Reference 7.

[a]Number in parenthesis indicates number of vents.
[b]Calculated from 1984 equipment counts and average CMA emission factors. Emissions rounded to two significant figures.

TABLE C-21. NITRILE ELASTOMER PRODUCTION FACILITIES FOR WHICH 1984 EMISSIONS DATA ARE AVAILABLE

Company	Location	Capacity in 1985, dry rubber or latex tons/yr (Mg/Yr)
B. F. Goodrich[a]	Akron, OH	0
Copolymer	Baton Rouge, LA	7,500[b] (6,800)[b]
Goodyear	Houston, TX	17,600 (16,000)
Goodyear[c]	Akron, OH	5,500 (5,000)
Sohio[d]	Lima, OH	[e]
Uniroyal Chemical Co.	Painesville, OH	18,000 (16,300)

Source: Reference 7.

[a]B. F. Goodrich closed its NBR facility in 1983. Facility still produced 8,377 tons/yr (7,600 Mg/yr) of vinyl pyridine.
[b]Value taken from the literature.
[c]Facility also produced about 165 tons/yr (150 Mg/yr) of ABS copolymer (3 percent of production).
[d]Facility's operating status in 1988 unknown.
[e]Company confidential.

TABLE C-22. BUTADIENE EMISSIONS (1984) FROM NITRILE ELASTOMER PRODUCTION FACILITIES[7]

Company	Vent Location	Process Vent Emissions tons/yr (Mg/yr)		Control Device	Control Efficiency (%)	Equipment Leaks - Uncontrolled[b] tons/yr (Mg/yr)
		Uncontrolled[a]	Controlled			
Facility A	Process A (46)	60.6 (55)	2.4 (2.2)	Boiler	96	---
Facility B[c]	Butadiene absorber	<0.07 (<0.06)	<0.001 (<0.001)	Boiler	99+	18.7 (17)
Facility C[d]	Blowdown tank (1)	35.3 (32)	3.5 (3.2)	Condenser	90	---
	Coagulator (1)	42.3 (38.4)	---	Chemical treatment	Unknown	
	Building (1)	3.2 (2.9)	---	None	0	
	Screening (1)	---	---	Chemical treatment	Unknown	
	Dewatering (1)	---	---	None	0	
	Dryer (2)	---	---	None	0	
Facility D[f]	Reactor (1)	---	---	Flare	99.9	---
	Absorber (1)	---	---	Flare	99.9	
	Distillation (1)	---	---	Flare	99.9	
	Screen/coagulation (2)	16.5 (15)	1.7 (1.5)	Steam stripper for acrylonitrile	90	
Facility E	Reactor (1)	220.0 (200)	0.2 (0.2)	Thermal oxidation	99.9	0.43 (0.39)

TABLE C-22. CONTINUED

Company	Vent Location	Process Vent Emissions tons/yr (Mg/yr) Uncontrolled[a]	Controlled	Control Device	Control Efficiency (%)	Equipment Leaks - Uncontrolled[b] tons/yr (Mg/yr)
Facility F[g]	Recycle receiver (1)	3.3 (3.0)	0.36 (0.33)	Scrubber	89	7.2 (6.5)
	Steam jets (2)	---	---	Steam stripper for acrylonitrile	90	
	Dryer (1)	---	---	Steam stripper for acrylonitrile	90	
	Tanks (8)	---	---	Steam stripper for acrylonitrile	90	

Source: Reference 7.

[a]Number in parentheses indicates the number of vents of this type.
[b]Calculated from 1984 equipment counts and average CMA emission factors. Emissions rounded to two significant figures.
[c]Facility was also an SB copolymer producer; total facility emissions were reported. Emissions apportioned to NBR production based on percent production resulting in nitrile elastomer--3 percent.
[d]Facility was also an ABS copolymer producer; total facility emissions were reported. Emissions apportioned to NBR production based on percent production resulting in nitrile elastomer--97 percent.
[e]Chemical treatment destroys residual acrylonitrile. The effect on butadiene is not known.
[f]Only equipment leaks emissions were apportioned using percent of capacity dedicated to nitrile elastomer.
[g]Facility was also an SB copolymer producer; total facility emissions were reported. Emissions apportioned to NBR production based on percent production resulting in nitrile elastomer--5 percent.

"---" means no data available.

TABLE C-23. MISCELLANEOUS USES OF BUTADIENE FOR WHICH EMISSIONS DATA ARE AVAILABLE [5]

Company	Location	Product	Mode of Operation	1986 Design Capacity tons/yr (Mg/yr)
ArChem Company	Houston, TX	Tetrahydrophthalic (THP) Anhydride	Batch	568 (515)
B. F. Goodrich Company	Akron, OH	Butadiene-vinylpyridine Latex	Batch (on demand)	Unknown
Denka (Mobay Synthetics Corporation)	Houston, TX	THP Acid	Batch	1,650 (1,500)
DuPont	Beaumont, TX	1,4-Hexadiene	Continuous	[a]
DuPont	Victoria, TX	Dodecanedioic Acid	Continuous (2 weeks per month due to low demand)	[a]
Kaneka Texas Corporation	Bayport, TX	MBS Resins	Batch	14,300 (13,000)
Phillips Chemical Company	Borger, TX	Butadiene Cylinders	Batch	535 (485)
		Butadiene-furfural Cotrimer[c]	Continuous, intermittent, about 65% of the time	50 (45)
		Sulfolane	Batch	Unknown
Rohm and Haas Company	Louisville, KY	MBS Resins	Batch	[a]
Shell Oil Company	Norco, LA	Sulfolane	Unknown	Unknown
Union Carbide	Institute, WV	Butadiene Dimers	Continuous	7,200 (6,500)

Source: Reference 5.

[a]Company confidential.

TABLE C-24. BUTADIENE EMISSIONS FROM PROCESS VENTS ASSOCIATED WITH MISCELLANEOUS USES OF BUTADIENE [5,8,9]

Chemical Produced	Company	Vent Location	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Butadiene cylinders	Facility A	Process vents	11.6 (10.5)	N/A	None	0
Butadiene dimers	Facility B	Feedpot, recycle pot, reactor, and three recovery stills	5.6 (5)	0.1 (0.1)	Flare	98
Butadiene-furfural cotrimer	Facility A	Reactor	Unknown	0	By-product butadiene dimer recovery	100
		Crude storage	10.9 (9.9)	N/A	None	0
Butadiene-vinylpyridine latex	Facility C	Process vents	353 (320)	0.35 (0.32)	Boiler	99.9
		Dryer	6.6 (6.0)	N/A	None	0
Dodecanedioic acid	Facility D	Butadiene dryer + two jets	<110 (<100)	<0.1 (<0.1)	Boiler	99.9
		Reactor	220 (200)	0.2 (0.2)	Boiler	99.9
1,4-Hexadiene	Facility E	Knockout pot	27.2 (24.7)	N/A	None	0
		Reactor, stripper, recycle condenser	Unknown	Unknown	Abatement collection system for waste liquids and vapors routed to a boiler	99.9
Methyl methacrylate-butadiene-styrene resins	Facility F	Reactor	110 (100)	0.1 (0.1)	Boiler	99.9
		Coagulator	6.6 (6.0)	N/A	None	0
		Dryer	6.6 (6.0)	N/A	None	0
	Facility G	Reactor	1.0 (0.9)	N/A	None	0

TABLE C-24. CONTINUED

Chemical Produced	Company	Vent Location	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Control Device	Control Efficiency (%)
Sulfolane	Facility H	Reactant recycle accumulator	1.73 (1.57)	0.034 (0.031)	Flare	98
		Light ends stripper	7.57 (6.87)	0.15 (0.14)	Flare	98
Sulfolane	Facility A	Caustic scrubber	99 (90)	N/A	None	0
		Sulfolene flakes caustic scrubber	32.3 (29.3)	N/A	None	0
		Sulfolane reactor	0	N/A	None	0

Sources: References 5, 8, and 9.

TABLE C-25. BUTADIENE EMISSIONS FROM EQUIPMENT LEAKS ASSOCIATED WITH MISCELLANEOUS USES OF BUTADIENE [5,8,9]

Chemical Produced	Company	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Controls	Control Efficiency (%)
Butadiene cylinders	Facility A	<0.1 (<0.1)	N/A	None	0
Butadiene dimers	Facility B	4.3 (3.9)	---	Ambient monitoring, double[a] mechanical[b][a] seals	0, 100
Butadiene-furfural cotrimer	Facility A	0.6 (0.5)	---	Rupture discs [c] [c]	100
Butadiene-vinylpyridine latex	Facility C	Unknown	0.61 (0.55)	Quarterly LDAR, some rupture discs	32, 100
1,4-Hexadiene	Facility D	67.7 (61.4)	59.3 (53.8)	Some double mechanical[d] seals,[d] some rupture discs, some closed sampling	___[e]
Dodecanedioic acid	Facility E	5.7 (5.2)	---	Visual inspections	0
Methyl methacrylate-butadiene-styrene resins	Facility F	4.0 (3.6)	---	Unknown	---
	Facility G	17.4 (15.8)	---	Ambient monitoring	0

TABLE C-25. CONTINUED

Chemical Produced	Company	Uncontrolled Emissions tons/yr (Mg/yr)	Controlled Emissions tons/yr (Mg/yr)	Controls	Control Efficiency (%)
Sulfolane	Facility A	14.7 (13.3)	N/A	None	0
	Facility H	1.8 (1.6)	N/A	None	0
Tetrahydrophthalic anhydride/acid	Facility I	2.4 (2.2)	---	Visual inspections	0

Source: References 5, 8, and 9.

[a]Excludes pumps with double mechanical seals.
[b]Ambient monitoring in the vicinity was being used to detect elevated VOC levels, a potential indication of equipment leaks.
[c]Excludes pressure relief devices since all are controlled.
[d]Excludes pumps with double mechanical seals and closed sampling ports.
[e]Each control is 100-percent effective; however, not all components are controlled, so overall reduction is not equal to 100 percent.
[f]For visual inspections, no reduction was given due to inadequate information.

"---" means no data available.

LDAR = leak detection and repair program.

REFERENCES FOR APPENDIX C

1. Memorandum from K. Q. Kuhn and R. A. Wassel, Radian Corporation, to the Butadiene Source Category Concurrence File, March 25, 1986. "Estimate of 1,3-Butadiene Emissions from Production Facilities and Emissions Reductions Achievable with Additional Controls."

2. Memorandum from R. A. Wassel and K. Q. Kuhn, Radian Corporation, to the Butadiene Source Category Concurrence File, April 8, 1986. "Estimates of 1,3-Butadiene Emissions from Styrene-Butadiene Copolymer Facilities and Emissions Reductions Achievable with Additional Controls."

3. Randall, J. L. et al., April 1989. *Fugitive Emissions from the 1,3-Butadiene Production Industry: A Field Study, Final Report*. Radian Corporation. Prepared for the 1,3-Butadiene Panel of the Chemical Manufacturers Association. p. 5-11.

4. Memorandum from E. P. Epner, Radian Corporation, to the Butadiene Source Category Concurrence File, March 27, 1986. "Estimates of 1,3-Butadiene from Polybutadiene Facilities and Emissions Reductions Achievable with Additional Controls."

5. Memorandum from K. Q. Kuhn and R. C. Burt, Radian Corporation, to the Butadiene Source Category Concurrence File, December 12, 1986. "Estimates of 1,3-Butadiene Emissions from Miscellaneous Sources and Emissions Reductions Achievable with Candidate NESHAP Controls."

6. Memorandum from E. P. Epner, Radian Corporation, to L. B. Evans, U.S. Environmental Protection Agency, Chemicals and Petroleum Branch, December 23, 1985. "Estimates of 1,3-Butadiene Emissions from Neoprene Facilities and Emissions Reductions Achievable with Additional Controls."

7. Memorandum from R. Burt and R. Howle, Radian Corporation, to L. B. Evans, U.S. Environmental Protection Agency, Chemicals and Petroleum Branch, January 29, 1986. "Estimates of Acrylonitrile, Butadiene, and Other VOC Emissions and Controls for ABS and NBR Facilities."

APPENDIX D

ESTIMATION METHODS FOR EQUIPMENT LEAKS

APPENDIX D

ESTIMATION METHODS FOR EQUIPMENT LEAKS

An estimate of equipment leak emissions of butadiene depends on the equipment type (e.g., pump seals, flanges, valves, etc.), the associated emission factor, and the number of process components. For batch processes, the hours per year that butadiene actually flows through the component is estimated from the reported percent of the year the equipment operates. For continuous processes, butadiene is assumed to flow through the equipment 8,760 hours per year.

In 1988 and 1989, the Chemical Manufacturer's Association established a panel to study butadiene emissions from equipment leaks. Out of this study, the panel produced average butadiene emission rates (see Table 4-7). These emission rates represent a range of controls at the facility in the study, thus they cannot be used to calculate uncontrolled emissions. For butadiene producers and major users of butadiene, these emission rates can be used to calculate emissions where the number of equipment components and time in service is known. The estimate for each component type is the product of the emission rate, the number of components, and the time in service.

$$\begin{bmatrix} \text{component-specific} \\ \text{emission rate,} \\ \text{lb/hr/component} \end{bmatrix} \text{x} \begin{bmatrix} \text{no. of equipment} \\ \text{components in} \\ \text{butadiene service} \end{bmatrix} \text{x} \begin{bmatrix} \text{no. of hrs/yr} \\ \text{in butadiene} \\ \text{service} \end{bmatrix}$$

The estimate for all equipment leaks is the sum of the total for each component type.

Where an uncontrolled estimate is of interest, EPA methods have been published in *Protocol for Equipment Leak Emission Estimates*.[1] These include:

- an average emission factor approach;
- a screening ranges approach;
- an EPA correlation approach; and
- a unit-specific correlation approach.

The approaches differ in complexity; however, greater complexity usually yields more accurate emissions estimates.

The simplest method, the average emission factor approach, requires that the number of each component type be known. For each component, the type of service (gas, light or heavy liquid), the butadiene content of the stream, and the time the component is in service are needed. This information is then multiplied by the EPA's average emission factors. Emission factors for SOCMI process units and refineries are shown in Tables D-1 and D-2. Emission factors for marketing terminals and oil and gas production are also provided in the document. However, these are not provided here as no data on butadiene from these industries were identified. This method is an improvement on using generic emissions developed from source test data, inventory data, and/or engineering judgement. However, this method should only be used if no other data are available because it may result in an overestimation of actual equipment leak emissions. For each component, estimated emissions are calculated as follows:

$$\begin{bmatrix} \text{No. of} \\ \text{equipment} \\ \text{components} \end{bmatrix} \text{x} \begin{bmatrix} \text{Weight \%} \\ \text{butadiene} \\ \text{in the stream} \end{bmatrix} \text{x} \begin{bmatrix} \text{Component-} \\ \text{specific} \\ \text{emission factor} \end{bmatrix} \text{x} \begin{bmatrix} \text{No. of hrs/yr in} \\ \text{butadiene service} \end{bmatrix}$$

TABLE D-1. SOCMI AVERAGE TOTAL ORGANIC COMPOUND EMISSION FACTORS FOR EQUIPMENT LEAKS

Equipment Type	Service	Emission Factor[a,b] lb/hr/source (kg/hr/source)
Valves	Gas	0.01313 (0.00597)
	Light liquid	0.00887 (0.00403)
	Heavy liquid	0.00051 (0.00023)
Pump seals[c]	Light liquid	0.0438 (0.0199)
	Heavy liquid	0.01896 (0.00862)
Compressor seals	Gas	0.502 (0.228)
Pressure relief valves	Gas	0.229 (0.104)
Connectors	All	0.00403 (0.00183)
Open-ended lines	All	0.0037 (0.0017)
Sampling connections	All	0.0330 (0.0150)

Source: Reference 1.

[a] The emission factors presented in this table for gas valves, light liquid valves, light liquid pumps, and connectors are revised SOCMI average emission factors.
[b] These factors are for total organic compound emission rates.
[c] The light liquid pump seal factor can be used to estimate the leak rate from agitator seals.

To obtain more accurate equipment leak emission estimates, one of the more complex estimation approaches should be used. These approaches require that some level of emissions measurement for the facility's equipment components be collected. These are described briefly, and the reader is referred to the EPA protocol document for the calculation details.

The screening ranges approach (formerly known as the leak/no leak approach) is based on a determination of the number of leaking and non-leaking components. This approach may be applied when screening data are available as either "greater than or equal to 10,000 ppmv" or as "less than 10,000 ppmv." Emission factors for SOCMI facilities for these two ranges of screening values are presented in Table D-3; Table D-4 contains emission

TABLE D-2. REFINERY AVERAGE EMISSION FACTORS

Equipment type	Service	Emission Factor (kg/hr/source)[a]
Valves	Gas	0.0268
	Light Liquid	0.0109
	Heavy Liquid	0.00023
Pump seals[b]	Light Liquid	0.114
	Heavy Liquid	0.021
Compressor seals	Gas	0.636
Pressure relief valves	Gas	0.16
Connectors	All	0.00025
Open-ended lines	All	0.0023
Sampling connections	All	0.0150

Source: Reference 1.

[a] These factors are for non-methane organic compound emission rates.
[b] The light liquid pump seal factor can be used to estimate the leak rate from agitator seals.

factors for refineries. Emission factors for marketing terminals and oil and gas production are also available from Reference 1; however, as noted above, no data on whether these industries are emission sources are available.

The EPA correlation approach offers an additional refinement to estimating equipment leak emissions by providing an equation to predict mass emission rate as a function of screening value for a specific equipment type. Correlation equations for SOCMI process units and for petroleum process units are provided in Reference 1, along with their respective correlation curves. The EPA correlation approach is preferred when actual screening values are available.[1]

The unit-specific correlation approach requires the facility to develop its own correlation equations and requires more rigorous testing, bagging, and analyzing of equipment leaks to determine mass emission rates.

TABLE D-3. SOCMI SCREENING VALUE RANGE TOTAL ORGANIC COMPOUND EMISSION FACTORS FOR EQUIPMENT LEAK EMISSIONS[a]

Equipment Type	Service	≥10,000 ppmv Emission Factor[b] lb/hr/source(kg/hr/source)	<10,000 ppmv Emission Factor[b] lb/hr/source(kg/hr/source)
Valves	Gas	0.1720 (0.0782)	0.000288 (0.000131)
	Light liquid	0.1962 (0.0892)	0.000363 (0.000165)
	Heavy liquid	0.00051 (0.00023)	0.00051 (0.00023)
Pump seals[c]	Light liquid	0.535 (0.243)	0.00411 (0.00187)
	Heavy liquid	0.475 (0.216)	0.00462 (0.00210)
Compressor seals	Gas	3.538 (1.608)	0.1967 (0.0894)
Pressure relief valves	Gas	3.720 (1.691)	0.0983 (0.0447)
Connectors	All	0.249 (0.113)	0.0001782 (0.0000810)
Open-ended lines	All	0.02629 (0.01195)	0.00330 (0.00150)

Source: Reference 1.

[a] The emission factors presented in this table for gas valves, light liquid valves, light liquid pumps, and connectors are revised SOCMI≥ 10,000/< 10,000 ppmv emission factors.

[b] These factors are for total organic compound emission rates.

[c] The light liquid pump seal factors can be applied to estimate the leak rate from agitator seals.

TABLE D-4. REFINERY SCREENING RANGES EMISSION FACTORS

Equipment Type	Service	≥10,000 ppmv Emission Factor (kg/hr/source)[a]	<10,000 ppmv Emission Factor (kg/hr/source)[a]
Valves	Gas	0.2626	0.0006
	Light Liquid	0.0852	0.0017
	Heavy Liquid	0.00023	0.00023
Pump seals[b]	Light Liquid	0.437	0.0120
	Heavy Liquid	0.3885	0.0135
Compressor seals	Gas	1.608	0.0894
Pressure relief valves	Gas	1.691	0.0447
Connectors	All	0.0375	0.00006
Open-ended lines	All	0.01195	0.00150

Source: Reference 1.

[a] These factors are for non-methane organic compound emission rates.
[b] The light liquid pump seal factors can be applied to estimate the leak rate from agitator seals.

Appendix A of the EPA protocol document provides example calculations for each of the approaches described above.

Adjusting any of the estimates derived from the EPA approaches requires that facility control practices be known. Table 4-9 presents control techniques and typical efficiencies by equipment component that may be applied to emission estimates for each component type.

REFERENCES FOR APPENDIX D

1. U.S. EPA. *Protocol for Equipment Leak Emission Estimates*. EPA-453/R-95-017. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, 1995. p. 2-10.

APPENDIX E

SUMMARY OF 1992 TRI AIR EMISSIONS DATA FOR 1,3-BUTADIENE

TABLE E-1. SUMMARY OF 1992 TRI AIR EMISSIONS DATA FOR 1,3-BUTADIENE

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
NA						Goodyear Tire & Rubber Co. Plant 5	Akron	OH	324	3,500	3,824	Assumed SIC Code 28
No data						Rohm & Haas Kentucky Inc.	Louisville	KY	2,300	8,600	10,900	
28	2819	2821	2834	2869	2979	Dow Chemical USA Midland Site	Midland	MI	5,720	14,009	19,729	2979 is an invalid code
2046	NA					Penford Prods. Co.	Cedar Rapids	IA	250	250	500	Point and non-point are avgs[b]
2369	2821	NA				Texas Eastman Company	Longview	TX	49,000	11,000	60,000	
2621	2672	2821	3081	NA		W.R. Grace & Co.	Owensboro	KY	115,300	18,500	133,800	2672 is an invalid code
2641	2821	3479	NA			Nashua Corp. Computer Products Div.	Merrimack	NH	36	36	72	
2812	2813	2819	2821	2822	2865	Dow Chemical Co. Texas Operations	Freeport	TX	52,000	46,000	98,000	
2812	2821	2869	NA			Dow Chemical Co. Louisiana Div.	Plaquemine	LA	41,000	12,000	53,000	
2812	2821	2869	NA			BF Goodrich BFG Intermediates Co. Inc.	Calvert City	KY	170	5,100	5,270	
2819	2821	2869	NA			Elf Atochem N.A. Inc	Axis	AL	12,886	2,325	15,211	
2821	2822	NA				BASF Corp.	Chattanooga	TN	150,000	1,600	151,600	
2821	NA					GE Chemicals Inc.	Washington	WV	20,000	60,000	80,000	
2821	NA					Reichhold Chemicals Inc.	Cheswold	DE	64,688	5,383	70,071	
2821	2869	NA				Rexene Corp. Polypropylene Plant	Odessa	TX	10,766	34,479	45,245	
2821	2869	NA				Phillips Petroleum Co. Houston Chemical Complex	Pasadena	TX	11,000	26,000	37,000	
2821	NA					Goodyear Tire & Rubber Co.	Calhoun	GA	12,332	19,552	31,884	
2821	NA					GE Chemicals Inc. Chemicals	Ottawa	IL	12,100	18,513	30,613	
2821	2869	NA				Union Carbide Chemicals & Plastics Co. Texas City Plant	Texas City	TX	19,696	10,409	30,105	
2821	2822	2865	NA			Uniroyal Chemical Co. Inc.	Painesville	OH	3,066	14,452	17,518	
2821	NA					Reichhold Chemicals Inc.	Chickamauga	GA	8,100	8,900	17,000	
2821	2869	NA				Quantum Chemical Corp. USI Div.	Clinton	IA	6,900	9,800	16,700	
2821						Kaneka Texas Corp.	Pasadena	TX	3,200	12,000	15,200	
2821						Rohm & Haas Unocal Chemical Division	Charlotte	NC	6,470	6,140	12,610	
2821	2869	2813	NA			Quantum Chemical Corp. La Porte	La Porte	TX	5,744	5,380	11,124	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2821	2869	NA				Quantum Chemical Corp. USI Div.	Morris	IL	3,000	7,200	10,200	
2821	3086	NA				Monsanto Co.	Addyston	OH	6,000	860	6,860	
2821	NA					Goodyear Tire & Rubber Co. Akron Polymer Plant	Akron	OH	892	2,979	3,871	
2821	3086	NA				Dow Chemical Dalton Site	Dalton	GA	40	1,800	1,840	
2821	3086	NA				Dow North America Allyn's Point Plant	Gales Ferry	CT	45	1,340	1,385	
2821	2899	2822	NA			Rhone-Poulenc Inc. Walsh Div.	Gastonia	NC	242	807	1,049	
2821	NA					Ricon Resins Inc.	Grand Junction	CO	750	250	1,000	Point and non-point are avgs[b]
2821	2869					Amoco Chemical Co.	Whiting	IN	250	750	1,000	Point and non-point are avgs[b]
2821	2822	NA				Rohm & Haas Delaware Valley Inc.	Kankakee	IL	120	300	420	
2821						Rohm & Haas Delaware Valley Inc.	La Mirada	CA	0	242	242	
2822	NA					Miles Inc. Polysar Rubber Div.	Orange	TX	4,400	350,000	354,400	
2822						Firestone Synthetic Rubber & Latex Co.	Orange	TX	7,000	93,000	100,000	
2822	NA					Ameripol Synpol Corporation	Port Neches	TX	2,300	81,500	83,800	
2822	NA					Goodyear Tire & Rubber Co. Houston Chemical Plant	Houston	TX	9,000	60,724	69,724	
2822	2869					Du Pont Pontchartrain Works	La Place	LA	56,000	5,200	61,200	
2822	NA					Zeon Chemicals Kentucky Inc.	Louisville	KY	26,841	33,844	60,685	
2822	2821	2869	NA			Goodyear Tire & Rubber Co. Beaumont Chemical Plant	Beaumont	TX	6,600	42,000	48,600	
2822	2821					BASF Corp.	Monaca	PA	38,000	17	38,017	
2822	2865	NA				Miles Inc.	Houston	TX	14,300	15,600	29,900	
2822						Firestone Synthetic Rubber & Latex Co.	Lake Charles	LA	4,000	24,540	28,540	
2822						Dynagen Inc. of General Tire Inc.	Odessa	TX	11,150	15,222	26,372	
2822	2865	2869	2873			Du Pont Beaumont Plant Beaumont Works	Beaumont	TX	8,997	6,568	15,565	
2822	NA					American Synthetic Rubber Corp.	Louisville	KY	0	14,000	14,000	
2822	3087					Shell Chemical Co.	Belpre	OH	2,300	8,400	10,700	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2822	NA					Copolymer Rubber & Chemical Corp.	Baton Rouge	LA	500	10,000	10,500	
2822	2891					Gencorp Polymer Prods. Latex	Mogadore	OH	650	5,000	5,650	
2822	NA					BASF Corp.	Chattanooga	TN	150	750	900	Non-point is avg[b]
2822						Enichem Elastomers Americas Inc.	Baytown	TX	250	250	500	Point and non-point are avgs[b]
2822	NA					Firestone Synthetic Rubber & Latex Co.	Akron	OH	39	117	156	
2865						Buffalo Color Corp.	Buffalo	NY	1,800	36,000	37,800	
2865	NA					Amoco Chemical Co. Plant B	Texas City	TX	14	173	187	
2869	2821	NA				Lyondell Petrochemical Co.	Channelview	TX	245,000	61,000	306,000	
2869	NA					Texas Petrochemicals Corporation	Houston	TX	37,240	125,710	162,950	
2869	NA					Occidental Chemical Corp.	Alvin	TX	13,000	95,400	108,400	
2869	NA					Amoco Chemical Co. Chocolate Bayou Plant	Alvin	TX	250	102,000	102,250	Point is avg[b]
2869	NA					Texaco Chemical Co.	Port Neches	TX	15,000	55,000	70,000	
2869	2865	2822				Exxon Chemical Co. Baton Rouge Chemical Plant	Baton Rouge	LA	5,900	55,000	60,900	
2869	2821	NA				Phillips 66 Co. Philtex/Ryton Complex	Borger	TX	33,000	25,000	58,000	
2869	2822	2821				BF Goodrich Co. Akron Chemical Plant	Akron	OH	25,000	21,000	46,000	
2869						Union Carbide Chemicals & Plastics Co. Institute WV Plant Ops.	Institute	WV	15,751	20,611	36,362	
2869						Oxy Petrochemical Inc. Corpus Christi Plant	Corpus Christi	TX	26,300	9,700	36,000	
2869						Exxon Chemical Co. Baytown Olefins Plant	Baytown	TX	15,000	19,000	34,000	
2869						Union Carbide Chemicals & Plastics Co. Seadrift Plant	Port Lavaca	TX	12,929	20,965	33,894	
2869	NA					Mobil Chemical Co. Olefins/Aromatics Plant	Beaumont	TX	2,547	29,005	31,552	
2869						Du Pont Sabine River Works	Orange	TX	26,522	3,428	29,950	
2869	2865	2819	NA			Texaco Chemical Co. Port Arthur Chemical Plant	Port Arthur	TX	12,000	8,300	20,300	
2869	NA					Union Texas Prods. Corp. Geismar Ethylene Plant	Geismar	LA	1,300	14,600	15,900	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2869						Du Pont Victoria Plant	Victoria	TX	10,158	5,250	15,408	
2869	NA					Oxy Petrochemicals Inc.	Sulphur	LA	90	14,073	14,163	
2869	NA					Mobil Chemical Corp.	Houston	TX	5,000	5,500	10,500	
2869	4463	NA				Union Carbide Chemicals & Plastics Co. Marine Terminal	Texas City	TX	9,905	0	9,905	
2869	2865	2819	NA			Vista Chemical Co. Lake Charles Chemical Complex	Westlake	LA	2,980	5,475	8,455	
2869	2821	2895				Chevron Chemical Co.	Baytowm	TX	0	6,159	6,159	
2869						Lubrizol Petroleum Chemicals Co.	Painesville	OH	3,922	853	4,775	
2869	NA					Lindau Chemicals Inc.	Columbia	SC	4,200	250	4,450	Non-point is avg[b]
2869	NA					Hoescht-Celanese Corp. Pampa Plant	Pampa	TX	1,600	0	1,600	
2869	NA					Westlake Petrochemicals Corp.	Sulphur	LA	1,033	83	1,116	
2869	2821					Exxon Chemical Americas Baytown Chemical Plant	Baytown	TX	87	810	897	
2869						Union Carbide Corp. Indl. Chemicals	Hahnville	LA	105	507	612	
2869	2821	2822	NA			Morton Intl. Inc. MPM	Moss Point	MS	250	250	500	Point and non-point are avgs[b]
2869	2879	3083	2087	2821		Phillips Research Center	Bartlesville	OK	24	243	267	
2869						Sea Lion Tech. Inc.	Texas City	TX	250	5	255	Point and non-point are avgs[b]
2869	2821	NA				Dixie Chemical Co. Inc.	Pasadena	TX	0	15	15	
2869	NA					Lubrizol Corp. Deer Park Plant	Deer Park	TX	0	5	5	Non-point is avg[b]
2879	2821	2869	NA			Monsanto Co.	Muscatine	IA	160,000	4,000	164,000	
2879	NA					Zeneca Inc. Perry Plant	Perry	OH	9,800	80	9,880	
2879	2822	NA				Dow Chemical Co.	Pittsburg	CA	310	1,500	1,810	
2891						Roberts Consolidated Ind. Inc.	Mexico	MO	250	0	250	Point is avg[b]
2899	3081	2822	NA			3M	Decatur	AL	1,400	740	2,140	
2911	NA					Chevron USA Products Co. Port Arthur Refinery	Port Arthur	TX	14,000	120,000	134,000	
2911	2869	NA				Shell Norco Manufacturing Complex E. Site	Norco	LA	3,200	92,000	95,200	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2911	2869	2865	2821			Shell Oil Co. Deer Park Mfg. Complex	Deer Park	TX	10,960	57,679	68,639	
2911	NA					Texaco Refining & Marketing Inc. Puget Sound Plant	Anacortes	WA	23,000	10,000	33,000	
2911	NA					Ashland Petroleum Co. St. Paul Park Refinery	Saint Paul Park	MN	17,046	0	17,046	
2911	NA					Mobil Oil Beaumont Refinery	Beaumont	TX	13,000	1,300	14,300	
2911						Star Ent. Inc. Delaware City Refinery	Delaware City	DE	0	13,000	13,000	
2911	2951	2992	NA			Amoco Oil Co. Whiting Refinery	Whiting	IN	0	8,600	8,600	
2911	NA					Hess Oil Virgin Islands Corp. (HOVIC)	Kingshill	VI	0	7,394	7,394	
2911	NA					Arco Cherry Point Refinery	Ferndale	WA	0	6,900	6,900	
2911	NA					Kerr-McGee Refining Corp.	Wynnewood	OK	320	3,900	4,220	
2911	2869	NA				Phillips 66 Co.	Sweeny	TX	0	3,402	3,402	
2911	NA					Star Ent. Inc. Port Arthur Plant	Port Arthur	TX	2,803	9	2,812	
2911	5171	NA				Exxon Baytown Refinery	Baytown	TX	2,580	174	2,754	
2911	NA					Ashland Petroleum Co. Canton Refinery	Canton	OH	256	2,162	2,418	
2911	NA					Conoco Lake Charles Refinery	Westlake	LA	130	1,500	1,630	
2911	2819	2869	NA			Citgo Petroleum Corp.	Lake Charles	LA	31	1,500	1,531	
2911	NA					Conoco Billings Refinery	Billings	MT	27	1,400	1,427	
2911	NA					Ultramar Inc.	Wilmington	CA	270	750	1,020	Non-point is avg[b]
2911	NA					Marathon Oil Co.	Texas City	TX	830	180	1,010	
2911	NA					Lion Oil Co.	El Dorado	AR	0	1,006	1,006	
2911	NA					Exxon Co. USA Benicia Refinery	Benicia	CA	580	400	980	
2911	5171	NA				Exxon Baton Rouge Refinery	Baton Rouge	LA	440	460	900	
2911	NA					BP Oil Co. Toledo Refinery	Oregon	OH	210	690	900	
2911	2819	NA				Phillips 66 Co.	Borger	TX	18	870	888	
2911	2999	NA				Conoco Ponca City Refinery	Ponca City	OK	510	350	860	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2911	NA					Chevron USA Products Co. Hawaiian Refinery	Kapolei	HI	5	750	755	Point and non-point are avgs[b]
2911	NA					Mobil Joliet Refinery Corp.	Joliet	IL	350	200	550	
2911	NA					Texaco Refining & Marketing Inc. Lap	Wilmington	CA	0	540	540	
2911	NA					Ashland Petroleum Co. Catlettsburg Refinery	Catlettsburg	KY	455	70	525	
2911	2951	NA				Chevron USA Inc. El Paso Refinery	El Paso	TX	400	110	510	
2911						Shell Oil Co. Anacortes Refinery	Anacortes	WA	2	500	502	
2911	NA					Cenex Refinery	Laurel	MT	250	250	500	Point and non-point are avgs[b]
2911	NA					Southwestern Refining Co. Inc.	Corpus Christi	TX	250	250	500	Point and non-point are avgs[b]
2911						Crown Central Petroleum Corp. Houston Refinery	Pasadena	TX	5	482	487	
2911	5171	NA				Exxon Billings Refinery	Billings	MT	0	460	460	
2911	NA					Amerada Hess Corp.	Purvis	MS	0	415	415	
2911	NA					Amoco Oil Co.	Mandan	ND	0	410	410	
2911	2869	2873	NA			Chevron Products Co. Pascagoula Refinery	Pascagoula	MS	0	390	390	
2911	NA					Phibro Refining Krotz Springs	Krotz Springs	LA	90	242	332	
2911	NA					Conoco Denver Refinery	Commerce City	CO	0	320	320	
2911	NA					Amoco Oil Co. Texas City Refinery	Texas City	TX	0	310	310	
2911	NA					Chevron USA Products Co. El Segundo Refinery	El Segundo	CA	0	310	310	
2911	NA					Chevron USA Products Co.	Philadelphia	PA	0	301	301	
2911						Fletcher Oil & Refining Co.	Carson	CA	250	5	255	Point and non-point are avgs[b]
2911	2869	2992	NA			Lyondell Petrochemical Co. Houston Refinery	Houston	TX	0	250	250	Non-point is avg[b]
2911	NA					Mobil Oil Paulsboro Refinery	Paulsboro	NJ	0	250	250	Non-point is avg[b]
2911	4613	NA				Total Petroleum Inc. Alma Refinery	Alma	MI	0	250	250	Non-point is avg[b]
2911	NA					Arco Prods. Co. LA Refinery	Carson	CA	4	240	244	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2911	NA					Shell Oil Co. Wood River Mfg. Complex	Roxana	IL	0	230	230	
2911						Phibro Energy USA Inc.	Texas City	TX	171	58	229	
2911	NA					Tosco Refining Co.	Martinez	CA	17	200	217	
2911	NA					Total Petroleum Inc.	Ardmore	OK	0	150	150	
2911	NA					Mobil Oil Corp. Chalmette Refinery	Chalmette	LA	9	140	149	
2911	NA					Valero Refining Co.	Corpus Christi	TX	98	38	136	
2911	NA					Sun Refining & Marketing Co.	Marcus Hook	PA	0	120	120	
2911	NA					Giant Refining Co. Ciniza	Jamestown	NM	100	10	110	
2911	NA					Texaco Refining & Marketing Inc.	Bakersfield	CA	80	29	109	
2911	NA					Diamond Shamrock Refining & Marketing Co. Three Rivers	Three Rivers	TX	0	100	100	
2911	NA					BP Oil Co. Ferndale Refinery	Ferndale	WA	51	46	97	
2911	5171					Exxon Eastside Chemical Plant	Linden	NJ	34	63	97	
2911	2869	NA				Texaco Refining & Marketing Inc.	El Dorado	KS	0	91	91	
2911	5171					Exxon Refining & Marketing Terminal	Linden	NJ	0	88	88	
2911	NA					Sun Refining & Marketing Co.	Oregon	OH	0	77	77	
2911	NA					Chevron USA Products Co. Richmond Refinery	Richmond	CA	0	74	74	
2911	NA					Sun Refining & Marketing Co.	Philadelphia	PA	0	58	58	
2911	NA					Phibro Energy USA Inc.	Houston	TX	7	49	56	
2911						Fina Oil & Chemical Co.	Port Arthur	TX	0	42	42	
2911	NA					Mobil Oil Corp. Torrence Refinery	Torrence	CA	16	15	31	
2911	NA					Texaco Refining & Marketing Inc.	Bakersfield	CA	9	22	31	
2911						Marathon Oil Co.	Detroit	MI	0	22	22	
2911	NA					Unocal Corp. Carson Plant	Carson	CA	1	20	21	
2911						Uno-Ven Co. Chicago Refinery	Lemont	IL	0	19	19	

TABLE E-1. CONTINUED

SIC1	SIC2	SIC3	SIC4	SIC5	SIC6	Facility Name	City	State	Point Air Release (lb/yr)[a]	Non-point Air Release (lb/yr)[a]	Total (lb/yr)[a]	Notes
2911	NA					Marathon Oil Co. Louisiana Refinery	Garyville	LA	5	12	17	Point is avg[b]
2911	NA					Sun Refining & Marketing Co.	Tulsa	OK	0	8	8	
2911	NA					Countrymark Cooperative Inc. Assn. Inc. Mt. Vernon Refinery	Mount Vernon	IN	0	5	5	Non-point is avg[b]
2911	2819	2869	NA			Shell Oil Co. Martinez Mfg. Complex	Martinez	CA	0	2	2	
2911	NA					Star Ent. Inc. PAAC	Port Neches	TX	1	0	1	
3312	NA					Bethlehem Steel Corp. Burns Harbor Div.	Burns Harbor	IN	0	250	250	Non-point is avg[b]
3579	NA					Xerox	Oklahoma City	OK	4,200	0	4,200	
8731	8711	8734	NA			Chevron Research & Technology Co.	Richmond	CA	1	0	1	

[a]Includes any controls in place at the facility.
[b]Air releases were given as a range. The data were averaged for the table.